Title

Infant Mortality: Development of a Proposed Update to the Dollfus Classification of Infant Deaths

Journal

Public Health Reports, 130(6)

ISSN

0033-3549

Authors

Nakamura, Ann M
Dove, Melanie S
Minnal, Archana
et al.

Publication Date

2015-11-01

DOI

10.1177/003335491513000613

Peer reviewed

Infant Mortality: Development of a Proposed Update to the Dollfus Classification of Infant Deaths

Ann M. Nakamura, MPH[a]
Melanie S. Dove, ScD, MPH[b]
Archana Minnal, MPH[b]
Mark Damesyn, DrPH[a]
Michael P. Curtis, PhD[b]

ABSTRACT

Objective. Identifying infant deaths with common underlying causes and potential intervention points is critical to infant mortality surveillance and the development of prevention strategies. We constructed an International Classification of Diseases 10th Revision (ICD-10) parallel to the Dollfus cause-of-death classification scheme first published in 1990, which organized infant deaths by etiology and their amenability to prevention efforts.

Methods. Infant death records for 1996, dual-coded to the ICD Ninth Revision (ICD-9) and ICD-10, were obtained from the CDC public-use multiple-cause-of-death file on comparability between ICD-9 and ICD-10. We used the underlying cause of death to group 27,821 infant deaths into the nine categories of the ICD-9-based update to Dollfus' original coding scheme, published by Sowards in 1999. Comparability ratios were computed to measure concordance between ICD versions.

Results. The Dollfus classification system updated with ICD-10 codes had limited agreement with the 1999 modified classification system. Although prematurity, congenital malformations, Sudden Infant Death Syndrome, and obstetric conditions were the first through fourth most common causes of infant death under both systems, most comparability ratios were significantly different from one system to the other.

Conclusion. The Dollfus classification system can be adapted for use with ICD-10 codes to create a comprehensive, etiology-based profile of infant deaths. The potential benefits of using Dollfus logic to guide perinatal mortality reduction strategies, particularly to maternal and child health programs and other initiatives focused on improving infant health, warrant further examination of this method's use in perinatal mortality surveillance.

[a]California Department of Public Health; Maternal, Child and Adolescent Health Program; Epidemiology, Assessment and Program Development Branch; Epidemiology, Evaluation, and Data Operations Section, Sacramento, CA

[b]California Department of Public Health, Maternal, Child and Adolescent Health Program; Epidemiology, Assessment and Program Development Branch; Surveillance, Assessment and Program Development Section, Sacramento, CA

Address correspondence to: Ann M. Nakamura, MPH, California Department of Public Health, Maternal, Child and Adolescent Health Program, Epidemiology, Assessment and Program Development Branch, 1615 Capitol Ave., MS-8304, PO Box 997420, Sacramento, CA 95899-7420; tel. 916-650-0438; fax 916-650-0308; e-mail <ann.nakamura@cdph.ca.gov>.

The International Classification of Diseases (ICD), published by the World Health Organization (WHO), serves as the standard for morbidity and mortality classification. Volume two of the ICD 10th revision (ICD-10) provides the structure used to collect, classify, process, and present mortality statistics over time and across geographic regions,[1,2] using a taxonomy that classifies deaths by general disease and affected organ or site. To ensure consistency in the presentation of mortality data across nations, WHO statisticians and medical officers create special tabulation lists with each revision of the ICD. These lists, modified for use in the United States by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics (NCHS), aggregate thousands of single underlying cause-of-death codes into meaningful categories that take into consideration the cause group's amenability to public health interventions. In the United States, NCHS's List of 130 Selected Causes of Infant Death is the longstanding method for aggregating cause codes for infant mortality surveillance.[3] One challenge of adapting this list to the statistical study of infant mortality is that contiguous code blocks do not necessarily reflect common etiologies.[4–6]

Alternative classification schemes for infant mortality have been proposed to improve the utility of the ICD underlying cause-of-death code groups for targeted public health efforts. Isolation of prematurity-related deaths, for example, has been a particular challenge for infant mortality surveillance.[6–9] To more accurately reflect deaths caused directly or indirectly by prematurity, NCHS has begun tracking preterm-related mortality using selected cause codes originally identified through a clinical and literature review of 20 leading causes of infant death.[5,10,11] Although this measure is specific to the impact of prematurity on infant mortality, by combining conditions from different sections of the ICD into one with a common set of health determinants, it is an example of the kind of causal grouping critical to health assessment and prevention efforts.

The Dollfus classification system, published in 1990 by researchers from the University of North Carolina at Chapel Hill and the North Carolina Center for Health Statistics, aggregates infant deaths based on common etiology and their amenability to prevention strategies[4] into eight mutually exclusive groups: prematurity and related conditions, congenital anomalies, Sudden Infant Death Syndrome (SIDS), obstetric conditions, birth asphyxia, perinatal infections, other infections, and external causes. In 2013, the State Infant Mortality Toolkit, developed through a collaboration among CDC, the Association of Maternal and Child Health Programs, the March of Dimes, and state and national experts in maternal and infant health, emphasized the importance of infant cause-of-death grouping, including Dollfus classification, to assess infant mortality.[12] This toolkit provides an analytical framework that is useful for Collaborative Improvement and Innovation Network (CoIIN) efforts directed toward infant mortality reduction,[13] Health Resources and Services Administration's Title V Maternal and Child Health program needs assessment,[14] and other initiatives to improve birth outcomes.[15] The toolkit examined comparability of Dollfus classification using published data aggregated into 130 rankable causes of infant death under ICD Ninth Revision (ICD-9) and ICD-10, cautioning that classification systems are limited by the quality of underlying cause-of-death data. Our method builds upon that earlier work, employing a statistical frequency-based approach applied to individual bridge-coded death records coded under both ICD versions.

The most recent update to the original Dollfus classification was published in 1999, when Sowards updated the system to facilitate its use with national data,[16] presenting a modified Dollfus classification built according to cause-of-death coding published in ICD-9. To date, a validated ICD-10 equivalent to the original logic employed by Dollfus et al. has yet to be published. We describe a mapping of Sowards' 1999 Modified Dollfus Classification Scheme for Causes of Infant Death (hereinafter, 1999 Modified Dollfus Scheme)[17] from ICD-9 to ICD-10 codes.

METHODS

Data sources

Individual ICD-9 codes published in Sowards' 1999 Modified Dollfus Scheme were mapped to ICD-10 codes through bridge coding.[17] Infant death records, dual-coded to both ICD-9 and ICD-10, were obtained from CDC's public-use multiple-cause-of-death file on comparability between ICD-9 and ICD-10, created from the 1996 data year multiple-cause-of-death file.

The dual-coded file included 28,551 infant death records with 778 distinct ICD-9 codes, 992 distinct ICD-10 codes, and 3,297 unique code combinations. Of the 28,551 infant death records, 730 were removed due to missing ICD-10 information, leaving 27,821 infant death records suitable for analysis of infant mortality.[17] Unusual ICD-9/ICD-10 pairings, defined as those representing less than 5% of all pairings for a particular four-digit ICD-9 code (1,647 pairs, 2,927 infant deaths), were removed to focus ICD-9 to ICD-10 Dollfus mapping efforts on the most common ICD-10 code assignments. After removing the 730 records unsuitable for analysis as well as 2,927 records with

the most unusual ICD-9/ICD-10 pairings, the final file used to develop the ICD-10 equivalent to Sowards' 1999 Modified Dollfus Scheme included 24,894 infant death records, 759 ICD-9 codes, 843 ICD-10 codes, and 1,650 unique code combinations.

ICD-9 to ICD-10 mapping of Dollfus categories. Mapping of ICD-10 codes to Dollfus groups began with assigning each of the 759 distinct ICD-9 codes to one of the categories in the modified Dollfus scheme published by Sowards. Under Sowards' 1999 Modified Dollfus Scheme, 265 of the 759 distinct ICD-9 codes were assigned to eight Dollfus categories, which accounted for most (81.5%) infant deaths (data not shown). The remaining 494 codes were ascribed to "not classified." The eight main categories were further divided into subcategories, based on the original ICD-9 code groups published by Dollfus et al. in 1990;[4] Sowards did not include subcategories in her update.[16]

A crosswalk between ninth- and 10th-revision Dollfus categorization was created by joining the 265 Dollfus-classified ICD-9 codes at each subcategory level to their corresponding ICD-10 codes, which produced a list of 419 distinct ICD-10 codes, each with at least one mapped Dollfus subcategory. Most 10th-revision cause codes (n=373, 89.0%) were associated with a single ICD-9-based Dollfus subcategory. ICD-10 codes that mapped to two or more subcategories involved conditions where advances in medical knowledge or changes to the cause selection rules likely gave rise to differences in underlying cause selection. For example, 37 infant deaths coded using ICD-10 were attributed to human immunodeficiency virus (HIV) (ICD-10 B20–B24). Most deaths (86.4%) were originally coded to HIV infection (ICD-9 042.0–044.9); the remaining five deaths were coded to diseases of the blood, circulatory, and respiratory systems and opportunistic conditions associated with advanced HIV disease.

To ensure each ICD-10 code was mapped to a single Dollfus subcategory, subcategory assignments were ranked based on frequency and checked for consistency with the comparable category codes for 130 selected causes of infant death according to the ICD-9 and ICD-10,[17] and grouped in the "not classified" category if they were not consistent with this list. Subcategories associated with the most frequent assignment that were also consistent with this list were accepted. When the most frequent assignment conflicted with this list, remaining subcategory assignments were reviewed in order of descending frequency until a consistent mapping was identified. For example, the most common underlying cause selected for deaths attributed to acute vascular disorder of the intestine (K55.0) under ICD-10 was infectious colitis, enteritis, and gastroenteritis (009.0) rather than codes associated with noninfectious enteritis and colitis (555–558). Because the latter, rather than the most frequent, codes were consistent with CDC's selected cause list, acute vascular disorder of the intestine was ascribed to "not classified" with other diseases of the digestive system. This process resulted in a mapped listing of unique ICD-10 codes with a preliminary Dollfus assignment.

Because the dual-coded file represents deaths that occurred and not all possible causes of death, once the ICD-10 codes in the file received preliminary assignment, the next step involved assessing the resulting ICD-10 code list for gaps. ICD-10 codes from the CDC dual-coded file were organized into NCHS-selected cause groups, ICD-10 chapters, and three-digit-code blocks to identify uncommon causes from each disease group. Individual members of ICD-10 blocks were added to the updated Dollfus scheme if they were members of the same block listed among CDC's 130 selected causes of infant death (e.g., infections with a predominantly sexual mode of transmission) or there was an established association with the Dollfus category in the ICD-10 title (e.g., "congenital malformation" for congenital anomalies) or in the scientific literature. After identifying any potential gaps in the ICD-9 to ICD-10 mapping due to rare causes of death at the three-digit block level, the ICD-9 to ICD-10 mapping was reviewed at the 10th-revision chapter level to identify potentially missing blocks of ICD-10 codes. Accidental poisoning (X40–X49), other accidents (W20–W64, W75–W99, X00–X39, and X50–X59), and sequelae of unspecified external cause (Y89.9), missing from the 1999 external-cause Dollfus group, were added to the external-cause category in our updated version.

Comparability statistics

Comparability ratios (CRs), which measure the degree of continuity between cause-of-death classification schemes,[18] were used to measure the level of agreement between our bridge-coded, updated Dollfus scheme and Sowards' 1999 Modified Dollfus Scheme. We based 95% confidence intervals (CIs) for the CRs on multinomial sampling theory, which accounted for the lack of independence between coding of deaths via ICD-9 (numerator) and ICD-10 (denominator).[18–20]

RESULTS

The original and updated ICD-9 versions of the Dollfus scheme are presented with the ICD-10 version, obtained using the bridge-coded file (Table 1). CRs, by primary cause category and subcategory, are also shown (Table 2).

Table 1. Comparison of the original[a] (1990), modified[b] (1999), and updated (2015) Dollfus infant death classification schemes and their corresponding International Classification of Diseases, Ninth[c] and Tenth[d] Revision codes, United States

Original Dollfus classification, 1990		*Sowards' Modified Dollfus, 1999*	*Updated Dollfus, 2015*	
Category and subcategory	*ICD-9 code*	*ICD-9 code*	*Category and subcategory*	*ICD-10 code*
Prematurity and related conditions			Prematurity and related conditions	
1. Extreme immaturity and other preterm infants	765.0, 765.1	765.0, 765.1	1. Short gestation and low birthweight	P070–P073
2. Intracranial hemorrhage	431.0, 767.0, 772.1	431.0, 767.0	2. Birth trauma, neonatal hemorrhage, and hematological disorders	P10–P15, P52–P54
3. Respiratory problems	769.0, 770.2–770.5, 770.7, 770.8	769.0, 770.2–770.5, 770.7, 770.8	3. Respiratory distress syndrome, interstitial emphysema, pulmonary hemorrhage, and atelectasis	P22, P25, P26, P280–P281
			4. Chronic respiratory distress syndrome, and respiratory diseases originating in the perinatal period	P27, P282–P289
4. Necrotizing enterocolitis	777.5	777.5	5. Necrotizing enterocolitis	P77
5. Other specified perinatal conditions	779.8	779.8	6. Neonatal cardiac failure and other cardiovascular disorders originating in the perinatal period	P29
Congenital anomalies			Congenital anomalies	
6. Nervous system	740.0, 741.0, 741.9, 742.0, 742.2, 742.3	740.0–759.9	7. Congenital malformations, deformations, and chromosomal anomalies, congenital disorders	Q00–Q99, D82, E25
7. Cardiac and circulatory system	745.0–745.2, 745.4–745.6, 746.7–746.9, 747.1, 747.3, 747.4, 747.9			
8. Pulmonary system	748.5, 748.6			
9. Diaphragm	756.6			
10. Renal	753.0			
11. Liver and gallbladder	751.6			
12. Patau's syndrome	758.1			
13. Edwards' syndrome	758.2			
14. Multiple anomaly	759.7			
15. Sudden Infant Death Syndrome	798.0	798.0–799.0	8. Sudden Infant Death Syndrome	R95
Obstetric conditions			Obstetric conditions	
16. Incompetent cervix, premature rupture of membranes	761.0, 761.1	761.0, 761.1	9. Incompetent cervix, premature rupture of membranes	P010–P011
17. Multiple pregnancy	761.5	761.5	10. Multiple pregnancy	P015
18. Placental abnormalities	762.0–762.2	762.0–762.2	11. Placental previa, separation, and placental abnormalities	P020–P022
Birth asphyxia			Birth asphyxia	
19. Unspecified fetal distress	768.4	768.4	12. Intrauterine hypoxia, birth asphyxia	P20–P21
20. Severe and unspecified birth asphyxia	768.5, 768.9	768.5, 768.9		

continued on p. 636

Table 1 (continued). Comparison of the original[a] (1990), modified[b] (1999), and updated (2015) Dollfus infant death classification schemes and their corresponding International Classification of Diseases, Ninth[c] and Tenth[d] Revision codes, United States

Original Dollfus classification, 1990		*Sowards' Modified Dollfus, 1999*	*Updated Dollfus, 2015*	
Category and subcategory	*ICD-9 code*	*ICD-9 code*	*Category and subcategory*	*ICD-10 code*
Perinatal infections			Perinatal infections	
21. Streptococcal meningitis	320.2	320.2	13. Streptococcal meningitis	G002
22. Maternal infections	760.1, 760.2, 760.8	760.1, 760.2, 760.8	14. Maternal renal and urinary tract diseases, maternal infections, and parasitic diseases	P001, P002
23. Chorioamnionitis	762.7	762.7	15. Chorioamnionitis	P027
24. Other perinatal infections	771.8	771.8	16. Bacterial sepsis, congenital pneumonia, and other infections specific to the perinatal period	P36, P23, P35, P37, P39
Other infections			Other infections	
25. Infectious and parasitic diseases	0–139	001.0–139.8	17. Other infectious and parasitic diseases	A00–B99, I330, I440
26. Bacterial, haemophilus, and pneumococcal meningitis	320.0, 320.1, 320.8, 320.9, 322.9	320.0, 320.1, 320.8, 320.9, 322.9	18. Bacterial haemophilus and pneumococcal meningitis	G000–G009, G03, G04
27. Respiratory infections	460–466, 480–487, 490	460.0–466.1, 480.0–487.8, 490.0–491.9	19. Influenza and pneumonia and other respiratory infections	J09–J18, J00–J06, J20–J22, J40
External causes			External causes	
28. Motor vehicle accidents	E810–E819	E810.0–E820.0	20. Accidents involving transportation	V01–V99
29. Accidental falls, drowning	E880–E888, E910, E830–E832	E880.0–E889.9, E910.0	21. Accidents involving falls	W00–W19
30. Accidents due to fire/flames	E890–E899	Not included		
31. Accidental obstruction/suffocation	E911–E915	E911.9	22. Accidental drowning and submersion, suffocation, aspiration, and asphyxiation	W65–W74, W79–W80
32. Homicide, neglect	E904, E960–E969	E904.0–E905.0, E960.0–E970.9	23. Assault and other intentional injuries	X89–Y09
33. Injuries if accidental or purposeful	E983–E988	E983.0–E989.9	24. Injuries with undetermined intent or unspecified cause	Y10–Y34
34. Unspecified accidents	E928.9, E980–E989	E928.9–E929.9	25. Other unintentional injuries	W20–W64, W75–W78, W81–W99, X00–X59
Not classified			Other causes	
			26. Neoplasms, anemias, and other conditions not otherwise specified (all remaining codes)	

[a]Dollfus C, Patetta M, Siegel E, Cross AW. Infant mortality: a practical approach to the analysis of the leading causes of death and risk factors. Pediatrics 1990;86:176-83.

[b]Sowards KA. What is the leading cause of infant mortality? A note on the interpretation of official statistics. Am J Public Health 1999;89:1752-4.

[c]Centers for Disease Control and Prevention (US), National Center for Health Statistics. ICD title & code cross reference file [cited 2014 Feb 2]. Available from: URL: http://www.cdc.gov/nchs/data/statab/gmwki_96.pdf

[d]World Health Organization. International statistical classification of diseases and related health problems—10th revision, volume 2, 2010 edition. Geneva: WHO Press; 2011.

ICD = International Classification of Diseases

Table 2. Number and percent of infant deaths in 1996 classified by Sowards' ICD-9 modified Dollfus scheme[a,b] (1999) and an updated ICD-10[c] Dollfus scheme (2015), with comparability ratios, United States

Cause-of-death category	*ICD-9 cause subcategory Sowards' Modified Dollfus, 1999 (ICD-9 codes)*	*Infant deaths N (percent)[d]*	*ICD-10 cause subcategory Updated Dollfus, 2015 (ICD-10 codes)*	*Infant deaths N (percent)[d]*	*Comparability ratio (95% CI)*
Prematurity and related conditions	Prematurity and related conditions, all	8,381 (30.1)	Prematurity and related conditions, all	8,976 (32.3)	1.07 (1.06, 1.08)
	Extreme immaturity and other preterm infants (765.0, 765.1)	3,836 (45.8)	Short gestation and low birthweight (P070–P073)	4,251 (47.4)	1.11 (1.10, 1.12)
	Subdural and cerebral hemorrhage (431.0, 767.0)	178 (2.1)	Birth trauma, neonatal hemorrhage, and hematological disorders (P10–P15, P52–P54)	520 (5.8)	2.92 (2.65, 3.22)
	Respiratory distress syndrome, emphysema, pulmonary hemorrhage, and atelectasis (769.0, 770.2–770.5)	1,946 (23.2)	Respiratory distress syndrome, interstitial emphysema, pulmonary hemorrhage, and atelectasis (P22, P25, P26, P280–P281)	2,255 (25.1)	1.16 (1.13, 1.19)
	Other respiratory problems (770.7, 770.8)	1,092 (13.0)	Chronic respiratory distress syndrome and respiratory diseases originating in the perinatal period (P27, P282–P289)	439 (4.9)	0.40 (0.38, 0.43)
	Necrotizing enterocolitis (777.5)	310 (3.7)	Necrotizing enterocolitis (P77)	370 (4.1)	1.19 (1.13, 1.26)
	Other conditions originating in the perinatal period (779.8)	1,019 (12.2)	Neonatal cardiac failure and other cardiovascular disorders originating in the perinatal period (P29)	1,141 (12.7)	1.12 (1.08, 1.16)
Congenital anomalies	Congenital anomalies (740.0–759.9)	6,330 (22.8)	Congenital malformations, deformations, and chromosomal anomalies; congenital disorders (Q00–Q99, D82, E25)	5,895 (21.2)	0.93 (0.92, 0.94)
SIDS	Sudden Infant Death Syndrome (798.0–799.0)	2,857 (10.3)	Sudden Infant Death Syndrome (R95)	3,006 (10.8)	1.05 (1.04, 1.06)
Obstetric conditions	Obstetric conditions, all	1,613 (5.8)	Obstetric conditions, all	1,647 (5.9)	1.02 (1.00, 1.04)
	Incompetent cervix and premature rupture of membranes (761.0, 761.1)	917 (56.9)	Incompetent cervix; premature rupture of membranes (P010–P011)	953 (57.9)	1.04 (1.02, 1.06)
	Multiple pregnancy (761.5)	208 (12.9)	Multiple pregnancy (P015)	198 (12.0)	0.95 (0.87, 1.04)
	Placenta previa and other complications of the placenta (762.0–762.2)	488 (30.3)	Placenta previa, separation, and placental abnormalities (P020–P022)	496 (30.1)	1.02 (0.98, 1.05)
Birth asphyxia	Birth asphyxia (768.4, 768.5, 768.9)	422 (1.5)	Intrauterine hypoxia, birth asphyxia (P20–P21)	560 (2.0)	1.33 (1.25, 1.41)
Perinatal infections	Perinatal infections, all	1,089 (3.9)	Perinatal infections, all	1,336 (4.8)	1.23 (1.18, 1.27)
	Streptococcal meningitis (320.2)	16 (1.5)	Streptococcal meningitis (G002)	23 (1.7)	1.44 (1.19, 1.73)
	Maternal infections (760.1, 760.2, 760.8)	45 (4.1)	Maternal renal and urinary tract diseases, maternal infections, and parasitic diseases (P001, P002)	12 (0.9)	0.27 (0.17, 0.43)
	Chorioamnionitis (762.7)	347 (31.9)	Chorioamnionitis (P027)	351 (26.3)	1.01 (0.98, 1.05)
	Other infection specific to the perinatal period (771.8)	681 (62.5)	Bacterial sepsis, congenital pneumonia, and other infections specific to the perinatal period (P36, P23, P35, P37, P39)	950 (71.1)	1.40 (1.33, 1.46)

continued on p. 638

Table 2 (continued). Number and percent of infant deaths in 1996 classified by Sowards' ICD-9 modified Dollfus scheme[a,b] (1999) and an updated ICD-10[c] Dollfus scheme (2015), with comparability ratios, United States

Cause-of-death category	*ICD-9 cause subcategory Sowards' Modified Dollfus, 1999 (ICD-9 codes)*	*Infant deaths N (percent)[d]*	*ICD-10 cause subcategory Updated Dollfus, 2015 (ICD-10 codes)*	*Infant deaths N (percent)[d]*	*Comparability ratio (95% CI)*
Other infections	Other infections, all	1,347 (4.8)	Other infections, all	1,013 (3.6)	0.75 (0.72, 0.78)
	Infectious and parasitic diseases (001.0–139.8)	698 (51.8)	Other infectious and parasitic diseases (A00–B99, I330, I440)	506 (50.0)	0.72 (0.68, 0.78)
	Bacterial, haemophilus, and pneumococcal meningitis (320.0, 320.1, 320.8, 320.9, 322.9)	84 (6.2)	Haemophilus, pneumococcal, and other bacterial meningitis; encephalitis, myelitis, and encephalomyelitis (G000–G009, G03, G04)	93 (9.2)	1.11 (1.01, 1.21)
	Diseases of the respiratory system (460.0–466.1, 480.0–487.8, 490.0–491.9)	565 (42.0)	Influenza and pneumonia and other respiratory infections (J09–J18, J00–J06, J20–J22, J40)	414 (40.9)	0.73 (0.70, 0.77)
External causes	External causes, all	656 (2.4)	External causes, all	1,050 (3.8)	1.60 (1.55, 1.65)
	Motor vehicle accidents (E810.0–E820.0)	205 (31.3)	Accidents involving transportation (V01–V99)	219 (20.9)	1.07 (1.03, 1.11)
	Accidents involving falls (E880.0–E889.9)	8 (1.2)	Accidents involving falls (W00–W19)	11 (1.1)	1.38 (0.82, 2.30)
	Accidental drowning, submersion, suffocation (E910.0–E911.9)	93 (14.2)	Accidental drowning and submersion, suffocation, aspiration, and asphyxiation (W65–W74, W79–W80)	110 (10.48)	1.18 (1.03, 1.36)
	Other and unspecified accidents (E928.9–E929.9)	16 (2.4)	Other unintentional injuries (W20–W64, W75–W78, W81–W99, X00–X59)	376 (35.8)	Not calculated[e]
	Assault and other intentional injuries (E960.0–E970.9)	300 (45.7)	Assault and other intentional injuries (X89–Y09)	300 (28.6)	1.00 (0.98, 1.02)
	Other injuries, undetermined whether accidental or on purpose (E983.0–E989.9)	34 (5.2)	Injuries with undetermined intent or unspecified cause (Y10–Y34)	34 (3.2)	1.00 (0.83, 1.20)
Other causes	Not classified (all remaining codes)	5,126 (18.4)	Other causes: neoplasms, anemias, and other conditions not otherwise specified (all remaining codes)	4,338 (15.6)	0.85 (0.83, 0.86)

[a]Sowards KA. What is the leading cause of infant mortality? A note on the interpretation of official statistics. Am J Public Health 1999;89:1752–4.

[b]Centers for Disease Control and Prevention (US), National Center for Health Statistics. ICD title & code cross reference file [cited 2014 Feb 2]. Available from: URL: http://www.cdc.gov/nchs/data/statab/gmwki_96.pdf

[c]World Health Organization. International statistical classification of diseases and related health problems—10th revision, volume 2, 2010 edition. Geneva: WHO Press; 2011.

[d]Percentages may not add up to 100 due to rounding.

[e]Not calculated due to the absence of reported deaths in the corresponding Dollfus subcategory for comparison. A number of deaths were associated with ICD-9 cause codes (e.g., E913: accidental mechanical suffocation) that were not specifically listed in the Modified Dollfus Scheme.

ICD = International Classification of Diseases

CI = confidence interval

SIDS = Sudden Infant Death Syndrome

Overall, Sowards made relatively minor changes to the 1990 Dollfus Scheme, augmenting the original scheme to include less frequent causes of death in the categories of prematurity and related conditions, congenital anomalies, other infections, and external causes. The substantial effect of classification in ICD-10 on Sowards' ICD-9-based scheme is shown. Among the nine main categories of infant death, all CRs except for obstetric conditions were significantly different from each other (Table 2).

Among the eight main categories (excluding deaths in the "not classified" category), prematurity and related conditions, congenital anomalies, SIDS, and obstetric conditions were the first, second, third, and fourth most common causes of infant death under both classification schemes. Similarities ended beyond the four most common causes of death, with other infections representing the fifth and seventh most frequently reported causes of death under ICD-9 and ICD-10 schemes, respectively (Table 2).

Among the eight main categories, those with the least comparability, in terms of differences between their CRs and 1, were birth asphyxia (CR=1.33, 95% CI 1.25, 1.41), other infections (CR=0.75, 95% CI 0.72, 0.78), and external causes (CR=1.60, 95% CI 1.55, 1.65) (Table 2). The greater number of deaths attributed to birth asphyxia and external causes under ICD-10 can be attributed to the large number of infant deaths assigned new perinatal codes under ICD-10 that were assigned to "not classified" under Sowards' ICD-9 scheme. Comparability in the external causes category was also affected by the inclusion of deaths associated with certain ICD-9 cause codes (e.g., E913: accidental mechanical suffocation) that were not listed in the Modified Dollfus Scheme. The lack of comparability between ninth- and 10th-revision Dollfus schemes in the category of other infections mainly reflects the reassignment of infections, such as those associated with the digestive system, to ICD-10 perinatal codes associated with the perinatal infections category.

The greatest overall change, in terms of number of deaths that moved in or out of any of the eight cause categories with the shift to ICD-10, involved deaths attributed to prematurity and related conditions, with 595 more deaths assigned under ICD-10 than under ICD-9 (Table 3). Only 87% (7,829/8,976) of infant deaths attributed to this category under ICD-10 were similarly assigned under ICD-9. Deaths moving into prematurity and related conditions under ICD-10 came mainly from congenital anomalies or the "not classified" category (Table 3). The CR for prematurity and related conditions was 1.07 (95% CI 1.06, 1.08), which means 7% more infant deaths were assigned to this category using ICD-10 compared with ICD-9 (Table 2).

In the ninth group, "not classified," changes in assignment were mainly due to expanded disease classifications, specifically the addition of terms newly assigned to perinatal codes under ICD-10 and the addition of deaths associated with external cause codes absent from Sowards' Modified Dollfus Scheme. Of the 5,126 deaths not classified under ICD-9, 3,485 remained not classified under ICD-10. The other 1,641 infant deaths shifted to other cause categories via the 10th-revision update. Of these 1,641 deaths, roughly one-third (n=502, 30.6%) moved to prematurity and related conditions and 23.9% (n=393) moved to external causes (Table 3).

DISCUSSION

The 1999 Modified Dollfus Scheme and our 10th-revision update were consistent in their ranking of the most common, broad cause categories of infant death: prematurity and related conditions, congenital anomalies, SIDS, and obstetric conditions.[16] However, beyond that, agreement was limited to a small number of conditions. The greatest discontinuities between the two schemes, in terms of the numbers of infant deaths reclassified, were seen in deaths attributable to prematurity and related conditions, which increased; congenital anomalies, which decreased; and deaths in the "not classified" category, which decreased.

Dollfus classification, which uses a single variable reported in all mortality datasets from the vital records system, provides an easily applied method for tabulating infant mortality statistics. This method also identifies deaths attributable to prematurity from death records alone, which could improve the timeliness of perinatal mortality surveillance efforts that rely on the linkage of death and birth records to obtain gestational age measures.

Another potential benefit of Dollfus classification is its potential expansion to include classification of fetal deaths. Certain underlying causes of infant death, such as influenza and pneumonia, are not suitable for classifying fetal deaths. However, many conditions, such as congenital anomalies that cause fatalities before and after delivery, share a common set of determinants and ICD-10 codes. Since Sowards' 1999 Modified Dollfus Scheme was published, CDC, in collaboration with state and local experts in maternal child health epidemiology and public health practice, launched an intensive effort to increase the utility of perinatal outcomes data for infant mortality investigations.[12,21,22] One focus

Table 3. Number and percent of infant deaths in 1996 classified by Sowards' ICD-9 modified Dollfus scheme[a,b] (1999) and an updated ICD-10[c] Dollfus scheme (2015), United States

	Cause of death Updated Dollfus, 2015									
Cause of death, Sowards' Modified Dollfus, 1999	*Prematurity and related conditions* N	*Congenital anomalies* N	*SIDS* N	*Obstetric conditions* N	*Birth asphyxia* N	*Perinatal infections* N	*Other infections* N	*External causes* N	*Not classified* N	*Total* N *(percent)*
Prematurity and related conditions	7,829	58	13	64	55	113	24	1	224	8,381 (30.1)
Congenital anomalies	429	5,552	20	10	9	15	12	3	280	6,330 (22.8)
Sudden Infant Death Syndrome	4	1	2,824	0	1	0	1	0	26	2,857 (10.3)
Obstetric conditions	54	0	3	1,525	3	6	1	0	21	1,613 (5.8)
Birth asphyxia	10	7	3	1	347	0	1	7	46	422 (1.5)
Perinatal infections	76	3	0	10	0	946	23	0	31	1,089 (3.9)
Other infections	72	51	19	0	0	118	867	0	220	1,347 (4.8)
External causes	0	2	2	0	1	0	0	646	5	656 (2.4)
Not classified	502	221	122	37	144	138	84	393	3,485	5,126 (18.4)
Total (percent)	8,976 (32.3)	5,895 (21.2)	3,006 (10.8)	1,647 (5.9)	560 (2.0)	1,336 (4.8)	1,013 (3.6)	1,050 (3.8)	4,338 (15.6)	27,821 (100.0)
Total net difference between ICD versions[d]	595	−435	149	34	138	247	−334	394	−788	Not applicable

[a]Sowards KA. What is the leading cause of infant mortality? A note on the interpretation of official statistics. Am J Public Health 1999;89:1752-4.

[b]Centers for Disease Control and Prevention (US), National Center for Health Statistics. ICD title & code cross reference file [cited 2014 Feb 2]. Available from: URL: http://www.cdc.gov/nchs/data/statab/gmwki_96.pdf

[c]World Health Organization. International statistical classification of diseases and related health problems—10th revision, volume 2, 2010 edition. Geneva: WHO Press; 2011.

[d]Values calculated by subtracting the number of infant deaths classified under the modified Dollfus scheme from infant deaths classified under the updated Dollfus scheme

ICD = International Classification of Diseases

of this effort is to increase capacity for the perinatal periods of risk (PPOR) approach to perinatal mortality. PPOR, proposed originally by Dr. Brian McCarthy and others at WHO in collaboration with CDC, expands the scope of traditional infant mortality investigations by integrating information from live births and fetal deaths into one analytical framework.[21] Expanding the scope of Dollfus' original scheme to incorporate fetal deaths is consistent with approaches such as PPOR and core perinatal mortality surveillance.

Limitations

This study was subject to several limitations. For one, gestational age measures were not included in the dual-coded mortality file used for this study; therefore, they were not used to validate the category prematurity and related conditions. As such, like the original Dollfus classification, deaths classified as prematurity-related in this updated scheme may not always involve preterm infants, a limitation detailed in previous studies.[5,23] Secondly, deaths due to intracranial hemorrhage in the original Dollfus classification scheme that mapped to birth trauma other than intraventricular hemorrhage (ICD-10 P102) and nontraumatic hemorrhage (P524) are examples of deaths that are not all prematurity specific but are included in the category prematurity and related conditions. Although these causes of infant death are less common, their inclusion points to a need for further investigation into the gestational age distribution of deaths in the category prematurity and related conditions and the ability of this method to complement other prematurity classification approaches, most notably the prematurity-related measure recently adopted for use in national statistics.[7]

Third, depending on the method used to select ICD-10 equivalents to ICD-9 codes for classification, the 1999 Modified Dollfus Scheme may have limited utility for trend analysis across ICD revisions. Modifications to the classification standards with ICD-10, particularly changes to rules that regulate selection of the underlying cause of death when more than one condition is listed, can significantly limit the ability to create a Dollfus-based scheme comparable with earlier ICD standards. Under ICD-10 Rule 3, a condition listed as a cause of death or as a contributing condition can be chosen as the underlying cause if there is medical or epidemiologic evidence that it initiated the chain of events that led to death. The impact of changes to Rule 3 and other selection rules on the classification of infant deaths is particularly relevant to the identification of prematurity-related deaths, which are multicausal, not yet fully understood, and subject to certification instructions that require the listing of additional conditions on the death certificate.

Fourth, the greater tendency of ICD-10 coding to classify deaths as being due to prematurity, as defined in this study, can make this codification less useful than CDC's special tabulation list of 130 selected causes of infant death, designed with continuity as a primary goal, for trend analyses involving deaths occurring before 1999 and those occurring thereafter. Applying Sowards' 1999 Modified Dollfus Scheme to deaths occurring before 1999 and this updated Dollfus scheme to deaths occurring after 1999 would distort statistical trends in maternal and infant health. Furthermore, similar to other classification schemes that aggregate deaths into a small number of mutually exclusive groups, Dollfus classification is not comprehensive. The modified (ICD-9) and updated (ICD-10) Dollfus schemes left 18.4% and 15.6% of deaths, respectively, "not classified."

CONCLUSION

Mapping Sowards' 1999 Modified Dollfus Scheme onto the ICD-10 is a potentially useful infant mortality classification tool that can be used for surveillance purposes, in addition to Callaghan's preterm-related conditions[5] and NCHS's list of 130 selected causes of infant death.[3] Bridge coding to ICD-10 is a starting point, and further examination using national or state infant death records is needed. With further study, this clearly defined, simple tool could be useful in guiding perinatal mortality reduction strategies in maternal and child health programs and other infant health improvement initiatives.

This study was determined to be exempt from review by the California Committee for the Protection of Human Subjects. The authors acknowledge Robert Anderson, PhD, for his assistance in the preliminary technical review of this study.

REFERENCES

1. World Health Organization. History of the development of the ICD [cited 2013 Jun 15]. Available from: URL: http://www.who.int/classifications/icd/en/HistoryOfICD.pdf
2. Centers for Disease Control and Prevention (US), National Center for Health Statistics. A guide to state implementation of ICD-10 for mortality. Hyattsville (MD): NCHS; 1998. Also available from: URL: http://ftp.cdc.gov/pub/health_statistics/NCHS/publications/ICD9_10con/let2.txt [cited 2013 Mar 10].
3. Centers for Disease Control and Prevention (US), National Center for Health Statistics. Instruction manual, part 9: ICD-10 cause-of-death lists for tabulating mortality statistics. Hyattsville (MD): NCHS; 2009. Also available from: URL: http://www.cdc.gov/nchs/nvss/instruction_manuals.htm [cited 2013 Mar 10].
4. Dollfus C, Patetta M, Siegel E, Cross AW. Infant mortality: a practical approach to the analysis of the leading causes of death and risk factors. Pediatrics 1990;86:176-83.

5. Callaghan WM, MacDorman MF, Rasmussen SA, Qin C, Lackritz EM. The contribution of preterm birth to infant mortality rates in the United States. Pediatrics 2006;118:1566-73.
6. Lawn JE, Osrin D, Adler A, Cousens S. Four million neonatal deaths: counting and attribution of cause of death. Paediatr Perinat Epidemiol 2008;22:410-6.
7. Institute of Medicine (US), Committee on Understanding Premature Birth and Assuring Healthy Outcomes; Behrman RE, Butler AS, editors. Preterm birth: causes, consequences, and prevention. Chapter 6: biological pathways leading to preterm birth. Washington: National Academies Press (US); 2006.
8. World Health Organization. International statistical classification of diseases and related health problems—10th revision, volume 2, 2010 edition. Geneva: WHO Press; 2011.
9. Centers for Disease Control and Prevention (US), National Center for Health Statistics. Physicians' handbook on medical certification of death. DHHS Publication No. (PHS) 2003-1108. Hyattsville (MD): Department of Health and Human Services (US); 2003.
10. Macdorman MF, Callaghan WM, Mathews TJ, Hoyert DL, Kochanek KD. Trends in preterm-related infant mortality by race and ethnicity, United States, 1999–2004. Int J Health Serv 2007; 37:635-41.
11. Mathews TJ, MacDorman, MF. Infant mortality statistics from the 2010 period linked birth/infant death data set. Natl Vital Stat Rep 2013 Dec 18;62:1-27.
12. Association of Maternal and Child Health Programs. Infant mortality toolkit. State infant mortality (SIM) toolkit: a standardized approach for examining infant mortality [cited 2013 Dec 9]. Available from: URL: http://www.amchp.org/programsandtopics/data-assessment/infantmortalitytoolkit/pages/default.aspx
13. Department of Health and Human Services (US), Health Resources and Services Administration. Collaborative Improvement & Innovation Network to Reduce Infant Mortality [cited 2015 Jun 26]. Available from: URL: http://mchb.hrsa.gov/infantmortality/coiin
14. Department of Health and Human Services (US), Health Resources and Services Administration. Title V maternal & child health block grant program needs assessment [cited 2015 Jun 26]. Available from: URL: http://mchb.hrsa.gov/programs/needsassessment
15. Kurtzman L. Children's hospitals launch global initiative on preterm birth with $100M from Lynne and Marc Benioff, Bill & Melinda Gates Foundation. University of California San Francisco News Center 2014 Apr 24 [cited 2015 Jun 26]. Available from: URL: www.ucsf.edu/news/2014/04/113646/ucsf-receive-100-million-gates-foundation-and-lynne-and-marc-benioff-fund-global
16. Sowards KA. What is the leading cause of infant mortality? A note on the interpretation of official statistics. Am J Public Health 1999; 89:1752-4.
17. Miniño AM, Anderson RN. Documentation for the public use multiple cause of death file on comparability between ICD-9 and ICD-10: a double-coded file based on the 1996 data year multiple cause of death file. Hyattsville (MD): National Center for Health Statistics (US); 2004.
18. Miniño AM, Parsons VL, Maurer JD, Rosenberg HM, Anderson RN, Kochanek KD, et al. A guide to state implementation of ICD-10 for mortality, part II: applying comparability ratios. Hyattsville (MD): National Center for Health Statistics (US); 2000.
19. Anderson RN, Miniño AM, Hoyert DL, Rosenberg HM. Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates. Natl Vital Stat Rep 2001 May 18;49:1-32.
20. Rooney C, Griffiths C, Cook L. The implementation of ICD-10 for cause of death coding—some preliminary results from the Bridge Coding Study. Health Stat Q 2002;13:31-41.
21. Sappenfield WM, Peck MG, Gilbert CS, Haynatzka VR, Bryant T III. Perinatal periods of risk: phase 2 analytic methods for further investigating feto-infant mortality. Matern Child Health J 2010;14:851-63.
22. CityMatCH. The perinatal periods of risk approach [cited 2013 Mar 5]. Available from: URL: http://www.citymatch.org/node/39
23. Klebanoff MA. Gestational age: not always what it seems. Obstet Gynecol 2007;109:798-9.