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Counting unintentional fatal drowning in Australia: ICD-10 coding based methodologies verses actual deaths

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Abstract

Objectives: Fatal drowning estimates using a single underlying cause of death (UCoD) may underrepresent the number of drowning deaths. This study explores how counts vary by ICD-10 coding combinations and the use of multiple underlying causes of death using a national register of drowning deaths.

Design: An analysis of ICD-10 external cause codes of unintentional drowning deaths for the period 2007-2011 as extracted from an Australian total population unintentional drowning database developed by Royal Life Saving Society - Australia (the Database). The study analysed results against three reporting methodologies; primary drowning codes (W65-74), drowning related codes, plus cases where drowning was identified but not the UCoD.

Setting: Australia, 2007-2011

Participants: Unintentional fatal drowning cases.

Results: The Database recorded 1,428 drowning deaths. 866 (60.6%) had an UCoD of W65-74 (accidental drowning), 249 (17.2%) cases had an UCoD of either T75.1 (0.2%), V90 (5.5%), V92 (3.5%), X38 (2.4%) or Y21 (5.9%) and 53 (3.7%) lacked ICD coding. Children (0-17 years) were closely aligned (73.9%), however watercraft (29.2%) and non-aquatic transport (13.0%) were not. When the UCoD and all subsequent causes are used 67.2% of cases include W65-74 codes. 91.6% of all cases had a drowning code.

Conclusions: Defining drowning with the codes W65-74 and using only the UCoD captures two-thirds of all drowning deaths in Australia. This is unevenly distributed with adults, watercraft and non-aquatic transport-related drowning deaths underrepresented. Using a wider inclusion of ICD codes, which are drowning-related and multiple causes of death minimises this underrepresentation. A narrow approach to counting drowning deaths will negatively impact the design of policy, advocacy and program planning.

Strengths and limitations of this study

- This is the first total population study in Australia to examine fatal drowning counts via ICD-10 classifications using single and multiple underlying causes of death.
- Three different reporting methodologies were used to describe unintentional fatal drowning compared to the total number of cases.
- The study provides a greater depth of understanding on how the grouping of ICD-10 codes and the number of included underlying causes of death can impact the fatal drowning count.
- Variation due to time taken to close coronial cases and reporting of official cause of death statistics may impact data quality.
- Coronial cases are investigated at the state and territory level in Australia and as such information varies between jurisdictions and is subject to change until cases are closed.
- These findings represent Australia and further work in other countries is required.

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Contributors: AEP and RCF conceptualised the study and gathered the fatality data in the Database. AM coded the data to ICD-10, critically revised the manuscript and approved the manuscript as submitted. AEP conducted the analysis. AEP and RCF drafted the manuscript and approved as submitted. PB and JS provided some interpretation of the data, revised it critically and approved the manuscript as submitted.

Competing Interests Statement: AEP, RCF and AM were responsible for collating data in the database from the Australian National Coronial Information System (NCIS).

Data Sharing Statement: With respect to the minimum dataset underlying this research, this data is available on request however as the data is via a third party (coronial data), ethical approval and permission from the data custodians, the Australian National Coronial Information System (NCIS) is required before the authors are able to provide their dataset to the person inquiring. There are strict ethical restrictions around use of this data and it can therefore not be sent to a public repository. Once ethical approval and permission from the NCIS as data custodians has been achieved, researchers can contact ncis@ncis.org.au to gain access to the data.

Ethics Approval: Victorian Department of Justice and Regulation Human Research Ethics Committee (CF/07/13729; CF/10/25057, CF/13/19798).

Introduction

Drowning is a leading cause of unintentional injury-related death (1, 2), with children (3-6) and low and middle income countries (LMICs) disproportionately affected (2). The epidemiology of fatal drowning (7) and risk factors leading to drowning are becoming increasingly understood (8-10), subject to the availability of appropriate data (2, 11, 12).

The main coding framework used internationally to describe deaths is the International Classification of Diseases (ICD). Global estimates and many studies rely on one level of cause of death, the underlying cause of death (UCoD), to classify a fatality. The medical certificate cause of death, recommended by the World Health Organization (WHO) for international use, was designed to facilitate the selection of the UCoD. When more than one condition is entered on the death certificate the underlying cause is selected using the coding rules of the relevant version of the ICD (13). Limitations around ICD codes (14, 15) include fidelity, accuracy of coding (including injury cause), location (11, 15) and activity information (15-17). Reporting of statistics using ICD coding has been found to underestimate disease and injury causes including sports and leisure activity-related hospitalizations (18), obesity in hospitalised children (19) and drowning deaths (20), distorting resource allocation for prevention.

There are various approaches to identifying and counting drowning deaths (21-23). The use of specific ICD codes is a common strategy which avoids double counting deaths but misses those with multiple causes. The 2014 Global Report on Drowning (2) used only one ICD code per fatality, impacting on the reporting of the world-wide burden, currently estimated at 372,000 unintentional drowning deaths (ICD codes W65-74) annually.

The Global Burden of Disease (GBD) uses a similar approach, estimating burden based on one cause of death (24). The most recently published GBD-injury study reports that drowning decreased worldwide by 27% from 1990-2013 (1). Deciding which ICD codes are included in these calculations and which is used as the primary code can impact the estimated number of deaths. In Australia, multiple cause of death codes are available (25), providing opportunities to fully capture the incidence of drowning.

In Australia, official statistics on cause of death are provided by the Australian Bureau of Statistics (ABS) (25). Data are derived from death certificates, which are then assigned ICD codes. To provide evidence for drowning prevention interventions, Royal Life Saving Society – Australia (RLSSA) maintains a National Unintentional Fatal Drowning Database (the Database). The Database is used to describe unintentional drowning in Australia (22, 26-30).

This study aims to use the Database to describe the coverage of ICD-10 classification of drowning (W65-74). This will include exploring the UCoD, subsequent levels and additional drowning-related ICD-10 codes (T75.1, V90, V92, X38 and Y21).

Methods

In Australia all sudden and unexpected deaths are investigated by a coroner to determine the circumstances and cause of death (31). All cases are recorded on the National Coronial Information System (NCIS), which is the primary source of information for the Database. Triangulation of data occurs via year-round monitoring of: media, police reports, Child Death Review Team reports, social media and reports from lifesaving clubs (32). All deaths where unintentional drowning was the primary or contributory cause of death are included in the Database.

The period 1 January 2007 to 31 December 2011 was extracted from the Database. This period was chosen to maximise the proportion of closed cases and those with ICD coding. Cases with an open coronial finding as to the victim's intent were included. Intentional cases (suicide, homicide, assault and infanticide) were excluded. Both open (still under investigation) and closed coronial cases were included. At the time of analysis, 94.2% of cases were closed. ICD coding was not provided in 3.7% of cases. Data is correct as at 31 December 2016.

Information contained within the database is a mix of coding extracted from the NCIS and coding developed to describe drowning cases. For the activity, a range of codes are used, including bathing, falls, non-aquatic transport, swimming/recreating and watercraft. The activity code of 'non-aquatic transport' covers drowning deaths as a result of vehicles not intended to be used in the water – such as motor vehicles (33).

ICD-10 (34) codes for drowning cases in the NCIS are drawn from the ABS (25). Cases are matched to the NCIS by the ABS and ICD codes provided (32). There are instances where an NCIS case does not have ICD-10 coding, generally due to the inability to match the cases between the NCIS and ABS (35). The proportion of NCIS cases with ICD coding varies by State and Territory, from a low of 85% to a high of 99% (36).

A maximum of 10 causes of death are able to be categorised within the NCIS. This information includes: the Underlying Cause of Death (UCoD) which is defined as the initiating cause or event which lead to death (37). Subsequent (multiple) causes are all other conditions, diseases, injuries or events detailed in the death certificate and are coded in sequence (38).

Information on sex, age, cause of death, location of drowning, activity immediately prior to drowning, state or territory of drowning location, the resident status of the person who drowned and ICD-10 coding were extracted from the NCIS and entered into the Database in IBM SPSS Statistics Version 20 (39). SPSS was used to perform chi-squared analysis. A modified Bonferonni correction as suggested by Keppel (40) was used. Case counts of three or fewer are Not Presented (NP) as per the ethical requirements.

Hereafter W65-74 are referred to as *primary drowning codes* and T75.1, V90, V92, X38 and Y21 are referred to as *drowning-related codes*.

This study analyses incidents where the relevant codes appear as the UCoD or any of the multiple causes. Three new variables were created to categorise cases with:

- UCoD W65-74;
- UCoD T75.1, V90, V92, X38 or Y21; and
- T75.1, W65-74, V90, 92, X38 or Y21 as a multiple cause of death (Table 1).

The presence of other ICD-10 codes as UCoD are also examined. T75.1 (a diagnostic code, rather than an external cause code) was included to assess potential underrepresentation of drowning, consistent with Passmore et al (41).

[INSERT TABLE ONE ABOUT HERE]

This study was approved by the Victorian Department of Justice and Regulation Human Research Ethics Committee (CF/07/13729; CF/10/25057, CF/13/19798).

Results

There were 1,428 unintentional drowning deaths in Australia (2007-2011). Of these, 83 cases (5.8%) were open and 53 (3.7%) had no ICD coding (Figure 1). The proportion of cases with W65-74 coding (60.6%) ranged from a low of 54.8% in 2011 to a high of 65.2% in 2008. The proportion of cases missing ICD coding decreased over time, from 6.4% in 2007, to 1.8% in 2011. (Figure 2)

[INSERT FIGURE 1 AROUND HERE]

[INSERT FIGURE 2 AROUND HERE]

From the Database, 866 cases (60.6%) had an ICD code of W65-74 as the UCoD (Figure 2). Drowning of children aged 0-17 years (X^2=34.47; p<0.001), drowning incidents which occurred at the beach (X^2=40.01; p<0.001); on rocks (X^2=25.48; p<0.001); in swimming pools (X^2=19.491; p<0.001); whilst diving (X^2=16.26; p<0.001); due to falls into water (X^2=56.43; p<0.001); while rock fishing (X^2=18.58; p<0.001); and while swimming and recreating (X^2=75.61; p<0.001) were significantly more likely to have a primary drowning code as the UCoD. (Table 2)

Adults aged 18 to 54 years (X^2=12.03; p=0.001), drowning incidents in ocean/harbour locations (X^2=46.64; p<0.001); river/creek/stream locations (X^2=28.66; p<0.001); and drowning incidents as a result of non-aquatic transport incidents (X^2=128.61; p<0.001) and watercraft incidents (X^2=109.09; p<0.001) were significantly less likely to record primary drowning codes (W65-74) as the UCoD. (Table 2)

The use of W65-74 as the UCoD only, underreports drowning incidents at ocean/harbour and river/creek/stream locations by 60.1% and 49.3% respectively compared to the Database. Similarly, drowning deaths as a result of watercraft and non-aquatic transport incidents are underrepresented by 70.8% and 87.0% respectively. (Table 2)

[INSERT TABLE 2 AROUND HERE]

Where ICD coding was present

Of the 1,375 cases with ICD coding, 246 (18.1%) recorded additional drowning codes (T75.1, V90, V92, X38, Y21) as the UCoD. Of these, Y21 and V90 accounted for 5.9% and 5.5% respectively (Figure 2). Drowning deaths at ocean/harbour locations and due to watercraft incidents recorded the highest proportion of additional drowning codes as the UCoD at 43.3% and 61.2% respectively.

Almost one fifth of all 1,428 drowning cases identified (263; 18.4%) recorded non-drowning codes as the UCoD. Cases with a higher proportion of non-drowning codes as the UCoD were drowning deaths as a result of non-aquatic transport (70.5% other non-drowning codes as the UCoD), drowning deaths as a result of bathing (35.1%) and drowning deaths which occurred in bathtub/spa baths (34.4%).

Of those with ICD coding, common non-drowning codes as the UCoD were G40-epilepsy (2.9%), I25-chronic ischaemic heart disease (1.7%), and R99-ill-defined and unknown cause of mortality (1.1%). Over half (52.7%) of the cases with ICD-10 coding available recorded a diagnostic code of T75.1 as a multiple cause.

There were 19 cases (1.3%) coded as intentional (X71) of which, on review, three were intentional. Five cases had consistent coding yet lacked corroborating evidence. In eleven cases the ICD code was intentional however the coronial finding was left open implying that they should be coded to Y21-undetermined intent.

No drowning codes

There were 63 cases (4.4%), classified as drowning that did not have a primary drowning or drowning-related code as the UCoD or as a subsequent cause. Common non-drowning codes as the UCoD were R99-ill-defined and unknown cause of mortality (23.8%) and I251-atherosclerotic heart disease of native coronary artery (11.1%). Cases coded R-99 at Level 1 were coded as such due to bodies being too decomposed to determine cause of death (26.7%), a body not being recovered (20.0%) or where an external-only autopsy was conducted (53.3%).

No ICD coding

There were 53 cases without ICD coding. This varied from a low of five cases in 2011 to a high of 19 cases in 2007. Of these cases 47 (88.7%) were closed (i.e. no longer under investigation by the coroner). 40 cases (75.5%) were males and 23 (43.4%) were aged 18-54 years. Drowning deaths in ocean/harbour locations recorded the highest number of cases without ICD codes (13; 24.5%), followed by swimming pools (12; 22.6%) and river/creek/stream locations (10; 18.9%). When examining cases without ICD coding by activity being undertaken immediately prior to drowning, falls (17; 32.1%) were the leading activity, followed by swimming/recreating and watercraft-related incidents (10; 18.9% each).

Discussion

In Australia, 61% of unintentional drowning deaths are captured when W65-74 codes are used at UCoD to estimate drowning incidents. This increases to 78% if primary drowning and drowning-related codes (T75.1, V90, V92, W65-74, X38 and Y21) are included; and when all drowning codes and multiple causes of death are allowed, it captures 92%.

Global implications

The disparities identified in this study have implications for LMICs. A high income country like Australia, with well-resourced coronial systems, a sophisticated national statistics agency and organisations devoted to aquatic education, rescue and resuscitation, records a 40% disparity in drowning cases when primary drowning codes W65-74 as the UCoD only are used. LMICs with fewer resources for rescue, body retrieval, investigation and coding are likely to experience even higher underrepresentation of drowning in official statistics. This has implications for resource allocation to drowning prevention and impacts global estimates (2).

Water-related transport

Water-related transport poses a challenge for identifying drowning deaths. In this study, only 29% of watercraft-related drowning incidents had a code of W65-74. There is no easy solution currently using the ICD-10 external cause codes to separate out drowning-related watercraft incidents from other causes of death. This has implications for countries with a large number of water transportation-related drowning deaths such as Finland (20), Philippines (42) and Uganda (43).

Non-aquatic transport-related drownings

In Australia, non-aquatic transport related drownings are most commonly as a result of driving across roads and causeways inundated during floods. Non-aquatic transport incidents are only recorded with a UCOD of W65-74 in 13% of incidents. Underrepresentation (by 35%) has also been observed in New Zealand (17). It should be noted that prevention of such deaths may not be achieved through traditional drowning prevention nor road traffic-related strategies. Risk mitigation strategies such as early warning systems, flood depth markers, warning signage, bridges and culverts may be more effective (44).

Drowning cases without ICD-10 drowning codes

A small number of cases (4%) did not have an ICD drowning code. There were 36 different codes used as the UCoD, commonly medical conditions (5%), however some (1%) were also related to the inability to recover a body, advanced decomposition or external-only autopsy.

The use of R-99 coding for drowning cases where a body is not recovered or not recovered prior to advanced decomposition, is an issue that is also likely to disproportionately affect LMICs and countries without death registries and timely retrieval. It is also an issue likely to affect isolated areas within a country (such as rural and remote locations), locations and activities where people are more likely to be recreating around water alone and countries that experience natural disasters due to flooding and storm surges, as well as mass drowning events including large scale water transportation accidents. The scale of drowning due to such factors may therefore be underreported, deprioritising effective prevention strategies.

The role of the coroner and the data collection agency

Linked with the use of R-99 codes for open cases without an assigned cause of death is the speed with which the coroner completes an investigation and closes a case. Deaths, including drowning, which are not certified by coroners before the ABS' cut-off date may also be permanently miscoded (31).

In federated countries such as Australia, where investigation by the coroner is undertaken at the State/Territory or regional level, there are jurisdictional differences in resourcing, time taken to close cases, case documentation and coding of cause(s) of death (45). On a State and Territory basis, the difference between jurisdictions with respect to cases with and without ICD coding ranged from 0.0% without ICD coding in the Australian Capital Territory to 6.7% in Queensland. This may lead to non-comparable estimates of drowning by jurisdiction on the basis of resourcing and case load, impacting resources for prevention.

The Database currently includes unintentional drowning cases only. This audit identified 1.3% of cases in the Database that the ABS had coded as intentional (X71). Such coding issues highlight why it may be easier to examine all drowning cases regardless of intent, although prevention strategies differ between unintentional and intentional drowning.

Prevention

An accurate estimate of the number of people who drown is important for prevention. The approach used can impact drowning death numbers as well as the profile. Examining deaths with multiple causes can provide rich data to aid in prevention (46). Contributory causes of death identified in this study include pre-existing medical conditions such as epilepsy and heart disease, and other external causes such as alcohol and drug toxicity. Since the introduction of multiple cause coding, NCIS data shows that, on average, two causes (and conditions) per death would be lost if only the single underlying cause was recorded. This loss of information would be a particular problem for deaths attributed to external causes (injury, poisoning and violence) which are classified by the circumstances of death, rather than according to the nature of injury (32).

Recognising risk factors will strengthen the evidence base for prevention and address the multiple causal factors of drowning. For example, for epilepsy-related drowning deaths, it is unclear if the prevention of such drowning deaths is best achieved through diagnosis and appropriate medication (treating the medical condition alone) or increased supervision around water for those with epilepsy. Research has identified epilepsy as contributing to increased risk of drowning among Australian children 0-14 years (47), and pre-existing medical conditions, particularly cardiac conditions, among elderly people who have drowned (29).

Limitations

This information represents Australia only and as such, further work in other countries is required. There was variation in missing ICD codes across Australia (range 0.0% in the Australian Capital

Territory and Western Australia to 6.7% in Queensland). Information correct as at 31 December 2016. Coronial data is subject to change until closed (5.8% open cases).

Conclusion

Depending upon who and how drowning deaths are counted, influences the number reported. This study found a 39% difference based on a single level, narrow drowning definition (W65-74). Where multiple cause of drowning codes were allowed, and an expanded number of ICD codes, this figure increased to 92%. Reporting of watercraft and non-aquatic transport-related drowning deaths is an ongoing challenge within the current ICD-10 external cause classification system. This has implications for the design of policy, advocacy and program planning for drowning prevention.

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Figure Legends

Figure 1: Flow chart of unintentional fatal drowning cases, Australia, 2007-2011 (N=1,428)

To be placed under the table - * Note: a given case may have multiple codes and as such this column of the flow chart will not sum to 100.0%.

Figure 2: Trends over time in unintentional fatal drowning by ICD W65-74 code as the UCoD, other ICD codes as the UCoD and cases with no ICD codes by calendar year, 2007-2011, Australia (N=1,428)

Table 1: ICD-10 drowning codes and other relevant codes (n=1,375)

As referred to within this study	ICD-10 Code		Definition	Number of cases as the UCoD (N)
Primary drowning codes (W65-74)		W65	Accidental drowning and submersion while in bathtub	40
		W66	Drowning and submersion following fall into bathtub	9
		W67	Drowning and submersion while in swimming pool	94
		W68	Drowning and submersion following fall into swimming pool	62
		W69	Drowning and submersion while in natural water	384
		W70	Drowning and submersion following fall into natural water	156
		W73	Other specified drowning and submersion	45
		W74	Unspecified drowning and submersion	76
Drowning-related codes		T75.1	Drowning and non-fatal submersion	3
		V90	Drowning and submersion due to accident to watercraft	78
		V92	Drowning and submersion due to accident on board watercraft, without accident to watercraft	50
		X38	Victim of flood	34
		Y21	Drowning and submersion, undetermined intent	84
Intentional drowning code		X71	Intentional self-harm by drowning and submersion	19
Examples of non drowning codes		G40	Epilepsy	40
		I25	Chronic ischaemic heart disease	23
		R99	Ill-defined and unknown cause of mortality	15
TOTAL				1,212

Table 2: RLSSA Database drowning cases compared to drowning cases with ICD-10 codes W65-74 as UCoD only by sex, age group, state or territory of drowning incident, category of aquatic location of drowning incident, activity immediately prior to drowning (N=1,428)

	RLSSA Database drowning cases	ICD-10 codes W65-74 as UCoD only	% difference	X^2 comparing all drowning deaths to the sub-sample of W65-74 as UCoD only (p value) *
Total	1428	866	39.4	-
Sex				
Male	1098	669	39.1	0.12 (p=0.73)
Female	330	197	40.3	
Age group				
0-17 years	268	198	26.1	34.47 (p<0.001)
18-54 years	709	401	43.4	12.03 (p=0.001)
55+ years	451	267	40.8	1.29 (p=0.26)
Resident status of drowning victim				
Australian	1343	809	39.8	3.60 (p=0.06)
Overseas	63	44	30.2	
Unknown	22	13	40.9	
State or Territory of drowning incident				
ACT	8	5	37.5	0.00 (p=0.98)
NSW	532	312	41.4	2.03 (p=0.15)
NT	43	28	34.9	0.25 (p=0.62)
QLD	360	207	42.5	0.36 (p=0.55)
SA	72	49	31.9	2.01 (p=0.16)
TAS	62	38	38.7	0.01 (p=0.91)
VIC	184	103	44.0	2.00 (p=0.16)
WA	167	124	25.7	10.36 (p=0.001)
Category of aquatic location of drowning incident				
Bathtub / Spa Bath	97	56	42.3	0.33 (p=0.57)
Beach	214	173	19.2	40.01 (p<0.001)
Lake / Dam / Lagoon	122	71	41.8	0.29 (p=0.59)
Ocean / Harbour	228	91	60.1	46.64 (p<0.001)
River / Creek / Stream	406	206	49.3	28.66 (p<0.001)
Rocks	77	67	13.0	25.48 (p<0.001)
Swimming Pool	222	161	27.5	19.91 (p<0.001)
Other / Unknown	62	41	33.9	0.77 (p=0.38)
Activity prior to drowning				
Bathing	98	56	42.9	0.50 (p=0.48)
Diving	69	57	17.4	16.26 (p<0.001)
Falls	292	227	22.3	56.43 (p<0.001)
Non-aquatic transport	115	15	87.0	128.61 (p<0.001)
Rock fishing	56	49	12.5	18.58 (p<0.001)
Swimming and recreating	304	249	18.1	75.61 (p<0.001)
Watercraft	216	63	70.8	109.09 (p<0.001)
Other	133	88	33.8	1.09 (p=0.30)
Unknown	145	62	57.2	26.37 (p<0.001)

Please note: those cases with unknown ICD coding are included in the Royal Life Saving Society – Australia column only. * calculated based on the ICD-10 codes W65-74 as UCoD only yes/no variable.

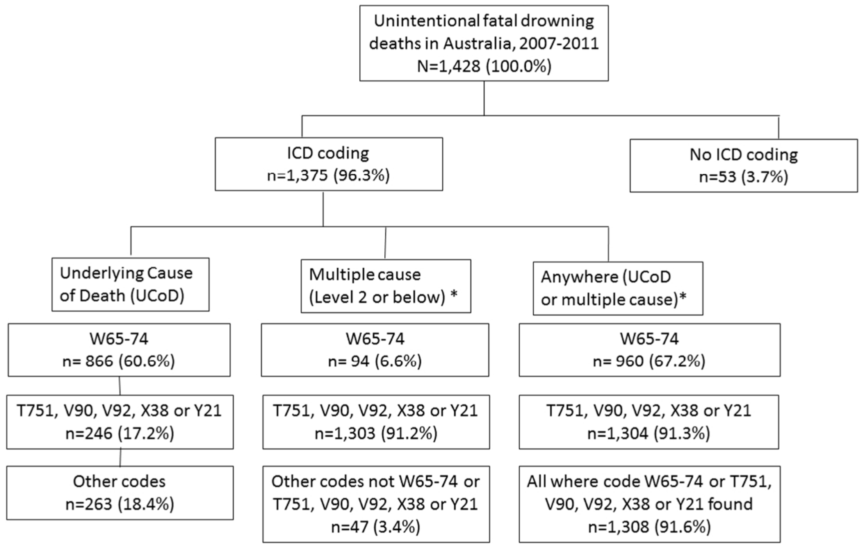

Figure 1: Flow chart of unintentional fatal drowning cases, Australia, 2007-2011 (N=1,428)

338x190mm (96 x 96 DPI)

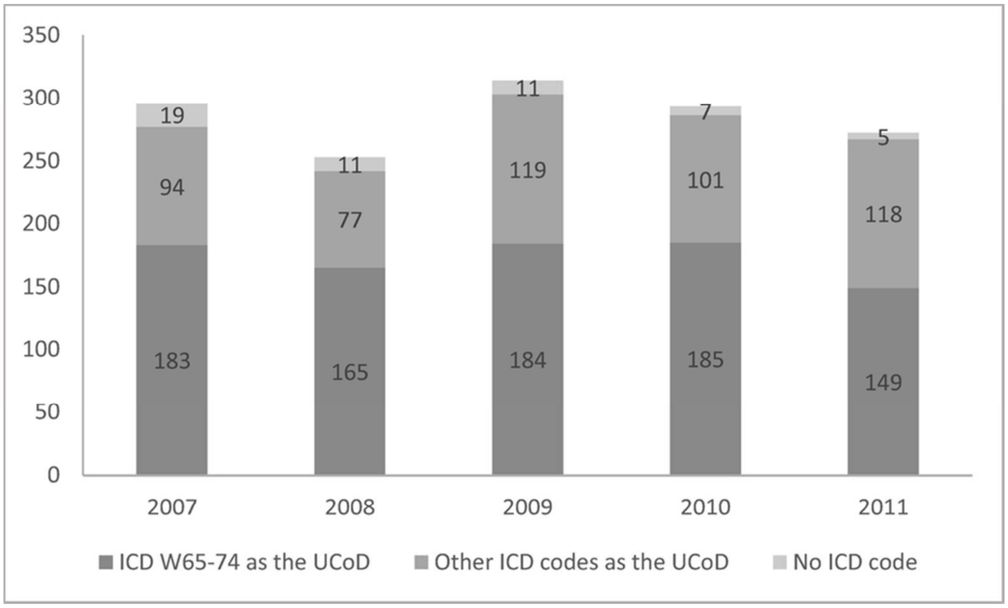

Figure 2: Trends over time in unintentional fatal drowning by ICD W65-74 code as the UCoD, other ICD codes as the UCoD and cases with no ICD codes by calendar year, 2007-2011, Australia (N=1,428)

76x45mm (300 x 300 DPI)

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Using a retrospective cross-sectional study to analyse unintentional fatal drowning in Australia: ICD-10 coding based methodologies verses actual deaths

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Using a retrospective cross-sectional study to analyse unintentional fatal drowning in Australia: ICD-10 coding based methodologies verses actual deaths

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Abstract

Objectives: Fatal drowning estimates using a single underlying cause of death (UCoD) may underrepresent the number of drowning deaths. This study explores how data varies by ICD-10 coding combinations and the use of multiple underlying causes of death using a national register of drowning deaths.

Design: An analysis of ICD-10 external cause codes of unintentional drowning deaths for the period 2007-2011 as extracted from an Australian total population unintentional drowning database developed by Royal Life Saving Society - Australia (the Database). The study analysed results against three reporting methodologies; primary drowning codes (W65-74), drowning related codes, plus cases where drowning was identified but not the UCoD.

Setting: Australia, 2007-2011

Participants: Unintentional fatal drowning cases.

Results: The Database recorded 1,428 drowning deaths. 866 (60.6%) had an UCoD of W65-74 (accidental drowning), 249 (17.2%) cases had an UCoD of either T75.1 (0.2%), V90 (5.5%), V92 (3.5%), X38 (2.4%) or Y21 (5.9%) and 53 (3.7%) lacked ICD coding. Children (0-17 years) were closely aligned (73.9%), however watercraft (29.2%) and non-aquatic transport (13.0%) were not. When the UCoD and all subsequent causes are used 67.2% of cases include W65-74 codes. 91.6% of all cases had a drowning code (T75.1, V90, V92, W65-74, X38 and Y21) at any level.

Conclusions: Defining drowning with the codes W65-74 and using only the UCoD captures 61% of all drowning deaths in Australia. This is unevenly distributed with adults, watercraft and non-aquatic transport-related drowning deaths underrepresented. Using a wider inclusion of ICD codes, which are drowning-related and multiple causes of death minimises this underrepresentation. A narrow approach to counting drowning deaths will negatively impact the design of policy, advocacy and program planning for prevention.

Strengths and limitations of this study

- This is the first total population study in Australia to examine fatal drowning counts via ICD-10 classifications using single and multiple underlying causes of death.
- Three different reporting methodologies were used to describe unintentional fatal drowning compared to the total number of cases.
- The study provides a greater depth of understanding on how the grouping of ICD-10 codes and the number of included underlying causes of death can impact the fatal drowning count.
- Variation due to time taken to close coronial cases and reporting of official cause of death statistics may impact data quality.
- Coronial cases are investigated at the state and territory level in Australia and as such information varies between jurisdictions and is subject to change until cases are closed.
- These findings represent Australia and further work in other countries is required.

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Contributors: AEP and RCF conceptualised the study and gathered the fatality data in the Database. AM coded the data to ICD-10, critically revised the manuscript and approved the manuscript as submitted. AEP conducted the analysis. AEP and RCF drafted the manuscript and approved as submitted. PB and JS provided some interpretation of the data, revised it critically and approved the manuscript as submitted.

Competing Interests Statement: AEP, RCF and AM were responsible for collating data in the database from the Australian National Coronial Information System (NCIS).

Data Sharing Statement: With respect to the minimum dataset underlying this research, this data is available on request however as the data is via a third party (coronial data), ethical approval and permission from the data custodians, the Australian National Coronial Information System (NCIS) is required before the authors are able to provide their dataset to the person inquiring. There are strict ethical restrictions around use of this data and it can therefore not be sent to a public repository. Once ethical approval and permission from the NCIS as data custodians has been achieved, researchers can contact ncis@ncis.org.au to gain access to the data.

Ethics Approval: Victorian Department of Justice and Regulation Human Research Ethics Committee (CF/07/13729; CF/10/25057, CF/13/19798).

Introduction

Drowning is a leading cause of unintentional injury-related death (1, 2), with children (3-6) and low and middle income countries (LMICs) disproportionately affected (2). The epidemiology of fatal drowning (7) and risk factors leading to drowning are becoming increasingly understood (8-10), subject to the availability of appropriate data (2, 11, 12).

The coding framework most frequently used internationally to describe deaths is the International Classification of Diseases (ICD). Global estimates and many studies rely on one level of cause of death, the underlying cause of death (UCoD), to classify a fatality. The medical certificate cause of death, recommended by the World Health Organization (WHO) for international use, was designed to facilitate the selection of the UCoD. When more than one condition is entered on the death certificate the underlying cause is selected using the coding rules of the relevant version of the ICD (13). Limitations around ICD codes (14, 15) include fidelity, accuracy of coding (including injury cause), location (11, 15) and activity information (15-17). Reporting of statistics using ICD coding has been found to underestimate disease and injury causes including sports and leisure activity-related hospitalizations (18), obesity in hospitalised children (19) and drowning deaths (20), distorting resource allocation for prevention.

There are various approaches to identifying and counting drowning deaths (21-23). The use of specific ICD codes is a common strategy which avoids double counting deaths but misses those with multiple causes. The 2014 Global Report on Drowning (2) used only one ICD code per fatality, impacting on the reporting of the world-wide burden, currently estimated at 372,441 unintentional drowning deaths (ICD codes W65-74) annually.

The Global Burden of Disease (GBD) uses a similar approach, estimating burden based on one cause of death (24). The most recently published GBD-injury study reports that drowning decreased worldwide by 27% from 1990-2013 (1). Deciding which ICD codes are included in these calculations and which is used as the primary code can impact the estimated number of deaths. In Australia, multiple cause of death codes are available (25), providing opportunities to fully capture the incidence of fatal drowning.

In Australia, official statistics on cause of death are provided by the Australian Bureau of Statistics (ABS) (25). Data are derived from death certificates, which are then assigned ICD codes. To provide evidence for drowning prevention interventions, Royal Life Saving Society – Australia (RLSSA) maintains a National Unintentional Fatal Drowning Database (the Database). The Database is used to describe unintentional drowning in Australia (22, 26-30).

This study aims to use the Database to describe the coverage of ICD-10 classification of drowning (W65-74). This will include exploring the UCoD, subsequent levels and additional drowning-related ICD-10 codes (T75.1, V90, V92, X38 and Y21).

Methods

In Australia all sudden and unexpected deaths are investigated by a coroner to determine the circumstances and cause of death (31). All cases are recorded on the National Coronial Information System (NCIS), which is the primary source of information for the Database. In addition to the NCIS, the Database uses triangulation of data via year-round monitoring of: media, police reports, Child Death Review Team reports, social media and reports from lifesaving clubs (32). All deaths where unintentional drowning was the primary or contributory cause of death are included in the Database.

The period 1 January 2007 to 31 December 2011 was extracted from the Database. This period was chosen to maximise the proportion of closed cases and those with ICD coding. Cases with a coronial finding of undetermined as to the victim's intent were included. Intentional cases (suicide, homicide, assault and infanticide) were excluded. Both open (still under investigation) and closed coronial cases were included. At the time of analysis, 94.2% of cases were closed. ICD coding was not provided in 3.7% of cases. Data is correct as at 31 December 2016.

Information contained within the database is a mix of coding extracted from the NCIS and coding developed to describe drowning cases. For the activity, a range of codes are used, including bathing, falls, non-aquatic transport, swimming/recreating and watercraft. The activity code of 'non-aquatic transport' covers drowning deaths as a result of vehicles not intended to be used in the water – such as motor vehicles (33).

ICD-10 (34) codes for drowning cases in the NCIS are drawn from the ABS (25). Cases are matched to the NCIS by the ABS and ICD codes provided (32). There are instances where an NCIS case does not have ICD-10 coding, generally due to the inability to match the cases between the NCIS and ABS (35). The proportion of NCIS cases with ICD coding varies by State and Territory, from a low of 85% to a high of 99% (36).

A maximum of 10 causes of death are able to be categorised within the NCIS. This information includes: the Underlying Cause of Death (UCoD) which is defined as the initiating cause or event which lead to death (37). Subsequent (multiple) causes are all other conditions, diseases, injuries or events detailed in the death certificate and are coded in sequence (38).

Information on sex, age, cause of death, location of drowning, activity immediately prior to drowning, state or territory of drowning location, the resident status of the person who drowned and ICD-10 coding were extracted from the NCIS and entered into the Database in IBM SPSS Statistics Version 20 (39). SPSS was used to perform chi-squared analysis. A modified Bonferonni correction as suggested by Keppel (40) was used. Case counts of three or fewer are Not Presented (NP) as per the ethical requirements.

Hereafter W65-74 are referred to as *primary drowning codes* and T75.1, V90, V92, X38 and Y21 are referred to as *drowning-related codes*.

This study analyses incidents where the relevant codes appear as the UCoD or any of the multiple causes. Three new variables were created to categorise cases with:

- UCoD W65-74;
- UCoD T75.1, V90, V92, X38 or Y21; and
- T75.1, W65-74, V90, 92, X38 or Y21 as a multiple cause of death (Table 1).

The presence of other ICD-10 codes as UCoD are also examined. T75.1 (a diagnostic code, rather than an external cause code) was included to assess potential underrepresentation of drowning, consistent with Passmore et al (41).

[INSERT TABLE ONE ABOUT HERE]

This study was approved by the Victorian Department of Justice and Regulation Human Research Ethics Committee (CF/07/13729; CF/10/25057, CF/13/19798).

Results

There were 1,428 unintentional drowning deaths in Australia (2007-2011). Of these, 83 cases (5.8%) were open and, of these, 53 (3.7%) had no ICD coding (Figure 1). The proportion of cases with W65-74 coding (60.6%) ranged from a low of 54.8% in 2011 to a high of 65.2% in 2008. The proportion of cases missing ICD coding decreased over time, from 6.4% in 2007, to 1.8% in 2011. (Figure 2)

[INSERT FIGURE 1 AROUND HERE]

[INSERT FIGURE 2 AROUND HERE]

From the Database, 866 cases (60.6%) had an ICD code of W65-74 as the UCoD (Figure 2). Drowning of children aged 0-17 years (X^2=34.47; p<0.001), drowning incidents which occurred at the beach (X^2=40.01; p<0.001); on rocks (X^2=25.48; p<0.001); in swimming pools (X^2=19.491; p<0.001); whilst diving (X^2=16.26; p<0.001); due to falls into water (X^2=56.43; p<0.001); while rock fishing (X^2=18.58; p<0.001); and while swimming and recreating (X^2=75.61; p<0.001) were significantly more likely to have a primary drowning code as the UCoD. (Table 2)

Adults aged 18 to 54 years (X^2=12.03; p=0.001), drowning incidents in ocean/harbour locations (X^2=46.64; p<0.001); river/creek/stream locations (X^2=28.66; p<0.001); and drowning incidents as a result of non-aquatic transport incidents (X^2=128.61; p<0.001) and watercraft incidents (X^2=109.09; p<0.001) were significantly less likely to record primary drowning codes (W65-74) as the UCoD. (Table 2)

The use of W65-74 as the UCoD only, underreports drowning incidents at ocean/harbour and river/creek/stream locations by 60.1% and 49.3% respectively compared to the Database. Similarly, drowning deaths as a result of watercraft and non-aquatic transport incidents are underrepresented by 70.8% and 87.0% respectively. (Table 2)

[INSERT TABLE 2 AROUND HERE]

Where ICD coding was present

Of the 1,375 cases with ICD coding, 246 (18.1%) recorded additional drowning codes (T75.1, V90, V92, X38, Y21) as the UCoD. Of these, Y21 and V90 accounted for 5.9% and 5.5% respectively (Figure 2). Drowning deaths at ocean/harbour locations and due to watercraft incidents recorded the highest proportion of additional drowning codes as the UCoD at 43.3% and 61.2% respectively.

Almost one fifth of all 1,428 drowning cases identified (263; 18.4%) recorded non-drowning codes as the UCoD. Cases with a higher proportion of non-drowning codes as the UCoD were drowning deaths as a result of non-aquatic transport (70.5% other non-drowning codes as the UCoD), drowning deaths as a result of bathing (35.1%) and drowning deaths which occurred in bathtub/spa baths (34.4%).

Of those with ICD coding, common non-drowning codes as the UCoD were G40-epilepsy (2.9%), I25-chronic ischaemic heart disease (1.7%), and R99-ill-defined and unknown cause of mortality (1.1%). Over half (52.7%) of the cases with ICD-10 coding available recorded a diagnostic code of T75.1 as a multiple cause.

There were 19 cases (1.3%) coded as intentional self-harm (X71) of which, on review, three were intentional. Five cases had consistent coding yet lacked corroborating evidence. In eleven cases the ICD code was intentional however the coronial finding was left open implying that they should be coded to Y21-undetermined intent. There were zero cases (0.0%) coded assault by drowning and submersion (X92).

No drowning codes

There were 63 cases (4.4%), classified as drowning that did not have a primary drowning or drowning-related code as the UCoD or as a subsequent cause. Common non-drowning codes as the UCoD were R99-ill-defined and unknown cause of mortality (23.8%) and I251-atherosclerotic heart disease of native coronary artery (11.1%). Cases coded R-99 at Level 1 were coded as such due to bodies being too decomposed to determine cause of death (26.7%), a body not being recovered (20.0%) or where an external-only autopsy was conducted (53.3%).

No ICD coding

There were 53 cases without ICD coding. This varied from a high of 19 cases in 2007 to a low in 2011 of five cases . Of these cases 47 (88.7%) were closed (i.e. no longer under investigation by the coroner). 40 cases (75.5%) were males and 23 (43.4%) were aged 18-54 years. Drowning deaths in ocean/harbour locations recorded the highest number of cases without ICD codes (13; 24.5%), followed by swimming pools (12; 22.6%) and river/creek/stream locations (10; 18.9%). When examining cases without ICD coding by activity being undertaken immediately prior to drowning, falls (17; 32.1%) were the leading activity, followed by swimming/recreating and watercraft-related incidents (10; 18.9% each).

Discussion

In Australia, during the study period, 61% of unintentional drowning deaths are captured when W65-74 codes are used at UCoD to estimate drowning incidents. This increases to 78% if primary drowning and drowning-related codes (T75.1, V90, V92, W65-74, X38 and Y21) are included; and when all drowning codes and multiple causes of death are allowed, it captures 92%.

Global implications

The disparities identified in this study have implications for LMICs. A high income country like Australia, with well-resourced coronial systems, a sophisticated national statistics agency and organisations devoted to aquatic education, rescue and resuscitation, records a 40% disparity in drowning cases when primary drowning codes W65-74 as the UCoD only are used. LMICs with fewer resources for rescue, body retrieval, investigation and coding are likely to experience even higher underrepresentation of drowning in official statistics. This has implications for resource allocation to drowning prevention due to the impacts of undercounting on community, national and global estimates (2). We would encourage all countries to have multiple causes of death provided, thus allowing for a greater understanding of the impact of drowning and the development of multi-faceted prevention strategies. All nations should be made aware of the challenges associated with, and prioritise, the collection and utilisation of drowning data.

Water-related transport

Water-related transport poses a challenge for identifying drowning deaths. In this study, only 29% of watercraft-related drowning incidents had a code of W65-74. There is no easy solution currently using the ICD-10 external cause codes to separate out drowning-related watercraft incidents from other causes of death. This has implications for estimates of fatal drowning and therefore resource allocation for prevention in countries with a large number of water transportation-related drowning deaths such as Finland (20), Philippines (42) and Uganda (43).

Non-aquatic transport-related drownings

In Australia, non-aquatic transport related drownings are most commonly as a result of driving across roads and causeways inundated during floods. Non-aquatic transport incidents are recorded with a UCOD of W65-74 in 13% of incidents, this underrepresentation has also been observed in

New Zealand (17). The challenge of such incidents is that traditional drowning prevention stratagems may not be effective as taking a road traffic-related approach. We posit that risk mitigation strategies for these drowning deaths may include early warning systems, flood depth markers, warning signage, bridges and culverts (44).

Drowning cases without ICD-10 drowning codes

A small number of cases (4%) did not have an ICD drowning code. There were 36 different codes used as the UCoD, commonly medical conditions (5%), however some (1%) were also related to the inability to recover a body, advanced decomposition or external-only autopsy.

The use of R-99 coding for drowning cases where a body is not recovered or not recovered prior to advanced decomposition, is an issue that is also likely to disproportionately affect LMICs and countries without death registries and timely retrieval. It is also an issue likely to affect isolated areas within a country (such as rural and remote locations), locations and activities where people are more likely to be recreating around water alone and countries that experience natural disasters due to flooding and storm surges. Countries that experience mass drowning events such as those due to large scale water transportation accidents are also likely to be affected by the use of R99. The scale of drowning due to such factors may therefore be underreported, deprioritising effective prevention strategies.

The role of the coroner and the data collection agency

Linked with the use of R-99 codes for open cases without an assigned cause of death is the speed with which the coroner completes an investigation and closes a case. Deaths, including drowning, which are not certified by coroners before the ABS' cut-off date may also be permanently miscoded (31).

In federated countries such as Australia, where investigation by the coroner is undertaken at the State/Territory or regional level, there are jurisdictional differences in resourcing, time taken to close cases, case documentation and coding of cause(s) of death (45). On a State and Territory basis, the difference between jurisdictions with respect to cases with and without ICD coding ranged from 0.0% without ICD coding in the Australian Capital Territory to 6.7% in Queensland. This may lead to non-comparable estimates of drowning by jurisdiction on the basis of resourcing and case load, impacting resources for prevention.

The Database currently includes unintentional drowning cases only. This audit identified 1.3% of cases in the Database that the ABS had coded as intentional (X71). Such coding issues highlight why it may be easier to examine all drowning cases regardless of intent, although prevention strategies differ between unintentional and intentional drowning.

Prevention

An accurate count of the number of people who drown (both fatal and non-fatal) is important for prevention. The approach used can impact drowning mortality numbers as well as the profile. The proportion of cases without ICD coding decreased across the study period, which has implications for drowning statistics in Australia. Future research should examine if similar trends are occurring in other countries. This study may also provide the impetus for other countries to conduct similar reviews of their own systems, thereby improving the quality and comparability of drowning data collected worldwide, as well as assist in improving WHO definitions, coding and global estimates.

Examining deaths with multiple causes can provide rich data to aid in prevention (46). Contributory causes of death identified in this study include pre-existing medical conditions such as epilepsy and heart disease, and other external causes such as alcohol and drug toxicity. Since the introduction of multiple cause coding, NCIS data shows that, on average, two causes (and conditions) per death would be lost if only the single underlying cause was recorded. This loss of information would be a particular problem for deaths attributed to external causes (injury, poisoning and violence) which are classified by the circumstances of death, rather than according to the nature of injury (32).

Recognising risk factors will strengthen the evidence base for prevention and address the multiple causal factors of drowning. For example, for epilepsy-related drowning deaths, it is unclear if the prevention of such drowning deaths is best achieved through diagnosis and appropriate medication (treating the medical condition alone) or increased supervision around water for those with epilepsy. Research has identified epilepsy as contributing to increased risk of drowning among Australian children 0-14 years (47), and pre-existing medical conditions, particularly cardiac conditions, among elderly people who have drowned (29).

Limitations

This study uses the Database of an Australian drowning prevention advocacy organisation, drawn from an online coronial database, as well as a range of other reports (for example police, media and child death review) that need to be corroborated by multiple sources. It is still possible there may be missing data (for example bodies missing at sea with no associated report). This information represents Australia only and as such, further work in other countries is required. There was variation in missing ICD codes across Australia (range 0.0% in the Australian Capital Territory and Western Australia to 6.7% in Queensland). Variation due to the time taken to close coronial cases and the reporting of official cause of death statistics may also impact data quality. The information is correct as of 31 December 2016. Coronial data is subject to change until closed (5.8% open cases).

Conclusion

Inclusion and exclusion in drowning mortality data collection and reporting produces substantial discrepancies that influence the illumination of the burden and resource allocation for prevention. This study found 61% of unintentional drowning deaths were captured when primary drowning codes were used (W65-74) as the UCoD only. Those cases not captured were commonly fatal drowning as a result of watercraft or non-aquatic transport incidents. When multiple cause codes were allowed, and an expanded number of ICD codes (T75.1, V90, V92, W65-74, X38 and Y21), this figure increased to 92%. Reporting of watercraft and non-aquatic transport-related drowning deaths is an ongoing challenge within the current ICD-10 external cause classification system. This has implications for the design of policy, advocacy and program planning for drowning prevention.

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Figure Legends

Figure 1: Flow chart of unintentional fatal drowning cases, Australia, 2007-2011 (N=1,428)

To be placed under the table - * Note: a given case may have multiple codes and as such this column of the flow chart will not sum to 100.0%.

Figure 2: Trends over time in unintentional fatal drowning by ICD W65-74 code as the UCoD, other ICD codes as the UCoD and cases with no ICD codes by calendar year, 2007-2011, Australia (N=1,428)

Table 1: ICD-10 drowning codes and other relevant codes (n=1,375)

As referred to within this study	ICD-10 Code	Definition	Number of cases as the UCoD (N)
Primary drowning codes (W65-74)	W65	Accidental drowning and submersion while in bathtub	40
	W66	Drowning and submersion following fall into bathtub	9
	W67	Drowning and submersion while in swimming pool	94
	W68	Drowning and submersion following fall into swimming pool	62
	W69	Drowning and submersion while in natural water	384
	W70	Drowning and submersion following fall into natural water	156
	W73	Other specified drowning and submersion	45
	W74	Unspecified drowning and submersion	76
Drowning-related codes	T75.1	Drowning and non-fatal submersion	3
	V90	Drowning and submersion due to accident to watercraft	78
	V92	Drowning and submersion due to accident on board watercraft, without accident to watercraft	50
	X38	Victim of flood	34
	Y21	Drowning and submersion, undetermined intent	84
Intentional drowning code	X71	Intentional self-harm by drowning and submersion	19
	X92	Assault by drowning and submersion	0
Examples of non drowning codes	G40	Epilepsy	40
	I25	Chronic ischaemic heart disease	23
	R99	Ill-defined and unknown cause of mortality	15
TOTAL			1,212

Table 2: RLSSA Database drowning cases compared to drowning cases with ICD-10 codes W65-74 as UCoD only by sex, age group, state or territory of drowning incident, category of aquatic location of drowning incident, activity immediately prior to drowning (N=1,428)

	RLSSA Database drowning cases	ICD-10 codes W65-74 as UCoD only	% difference	X^2 comparing all drowning deaths to the sub-sample of W65-74 as UCoD only (p value) *
Total	1428	866	39.4	-
Sex				
Male	1098	669	39.1	0.12 (p=0.73)
Female	330	197	40.3	
Age group				
0-17 years	268	198	26.1	34.47 (p<0.001)
18-54 years	709	401	43.4	12.03 (p=0.001)
55+ years	451	267	40.8	1.29 (p=0.26)
Resident status of drowning victim				
Australian	1343	809	39.8	3.60 (p=0.06)
Overseas	63	44	30.2	
Unknown	22	13	40.9	-
State or Territory of drowning incident				
ACT	8	5	37.5	0.00 (p=0.98)
NSW	532	312	41.4	2.03 (p=0.15)
NT	43	28	34.9	0.25 (p=0.62)
QLD	360	207	42.5	0.36 (p=0.55)
SA	72	49	31.9	2.01 (p=0.16)
TAS	62	38	38.7	0.01 (p=0.91)
VIC	184	103	44.0	2.00 (p=0.16)
WA	167	124	25.7	10.36 (p=0.001)
Category of aquatic location of drowning incident				
Bathtub / Spa Bath	97	56	42.3	0.33 (p=0.57)
Beach	214	173	19.2	40.01 (p<0.001)
Lake / Dam / Lagoon	122	71	41.8	0.29 (p=0.59)
Ocean / Harbour	228	91	60.1	46.64 (p<0.001)
River / Creek / Stream	406	206	49.3	28.66 (p<0.001)
Rocks	77	67	13.0	25.48 (p<0.001)
Swimming Pool	222	161	27.5	19.91 (p<0.001)
Other / Unknown	62	41	33.9	0.77 (p=0.38)
Activity prior to drowning				
Bathing	98	56	42.9	0.50 (p=0.48)
Diving	69	57	17.4	16.26 (p<0.001)
Falls	292	227	22.3	56.43 (p<0.001)
Non-aquatic transport	115	15	87.0	128.61 (p<0.001)
Rock fishing	56	49	12.5	18.58 (p<0.001)
Swimming and recreating	304	249	18.1	75.61 (p<0.001)
Watercraft	216	63	70.8	109.09 (p<0.001)
Other	133	88	33.8	1.09 (p=0.30)
Unknown	145	62	57.2	26.37 (p<0.001)

Please note: those cases with unknown ICD coding are included in the Royal Life Saving Society – Australia column only. * calculated based on the ICD-10 codes W65-74 as UCoD only yes/no variable.

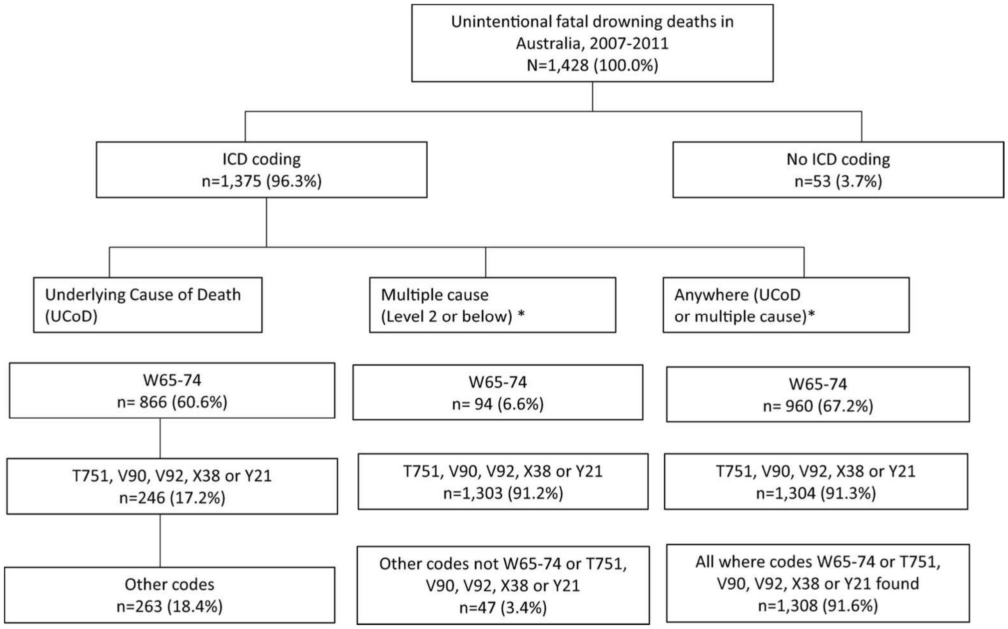

Figure 1: Flow chart of unintentional fatal drowning cases, Australia, 2007-2011 (N=1,428)
To be placed under the table - * Note: a given case may have multiple codes and as such this column of the flow chart will not sum to 100.0%.

144x89mm (300 x 300 DPI)

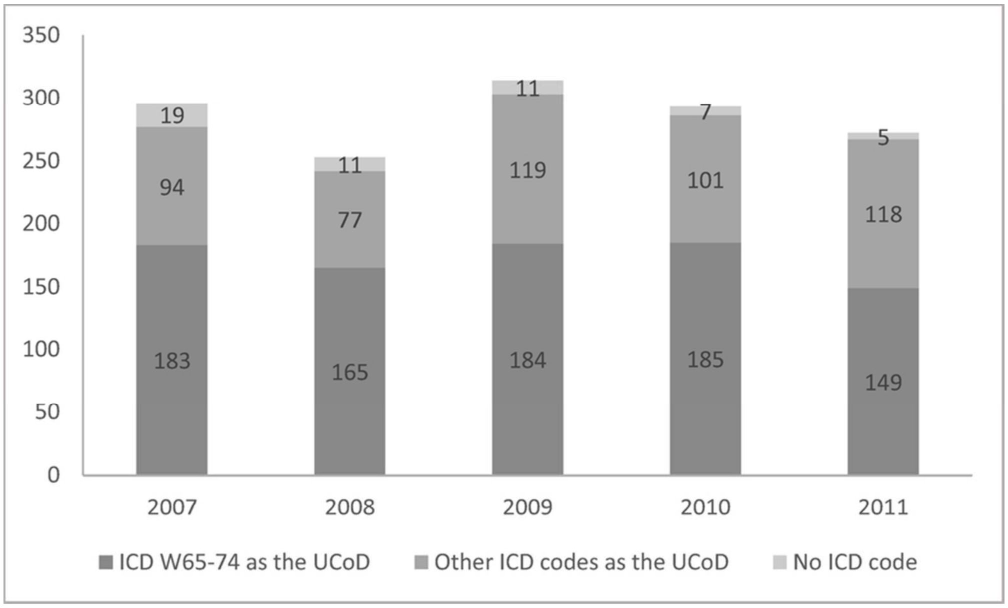

Figure 2: Trends over time in unintentional fatal drowning by ICD W65-74 code as the UCoD, other ICD codes as the UCoD and cases with no ICD codes by calendar year, 2007-2011, Australia (N=1,428)

76x45mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Page Number	Item No	Recommendation
Title and abstract	1	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
Introduction			
Background/rationale	5-6	2	Explain the scientific background and rationale for the investigation being reported
Objectives	6	3	State specific objectives, including any prespecified hypotheses
Methods			
Study design	6-8	4	Present key elements of study design early in the paper
Setting	6	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
	N/A		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	7	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
Bias	7	9	Describe any efforts to address potential sources of bias
Study size	6	10	Explain how the study size was arrived at
Quantitative variables	7	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	7	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
	N/A		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
	N/A		(*e*) Describe any sensitivity analyses

Continued on next page

Results			
Participants	8	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
	N/A		(b) Give reasons for non-participation at each stage
	19		(c) Consider use of a flow diagram
Descriptive data	8	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
	N/A		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	N/A	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
	N/A		*Case-control study*—Report numbers in each exposure category, or summary measures of exposure
	8-10		*Cross-sectional study*—Report numbers of outcome events or summary measures
Main results	8-9, 21	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
	21		(*b*) Report category boundaries when continuous variables were categorized
	N/A		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	8-10	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion			
Key results	10-11	18	Summarise key results with reference to study objectives
Limitations	14	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	14-15	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	14-15	21	Discuss the generalisability (external validity) of the study results
Other information			
Funding	3	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

*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.