

Risk of suicide after a concussion

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ABSTRACT

Background: Head injuries have been associated with subsequent suicide among military personnel, but outcomes after a concussion in the community are uncertain. We assessed the long-term risk of suicide after concussions occurring on weekends or weekdays in the community.

Methods: We performed a longitudinal cohort analysis of adults with diagnosis of a concussion in Ontario, Canada, from Apr. 1, 1992, to Mar. 31, 2012 (a 20-yr period), excluding severe cases that resulted in hospital admission. The primary outcome was the long-term risk of suicide after a weekend or weekday concussion.

Results: We identified 235 110 patients with a concussion. Their mean age was 41 years, 52% were men, and most (86%) lived in an urban location. A total of 667 subsequent suicides occurred over a median follow-up of 9.3 years,

equivalent to 31 deaths per 100 000 patients annually or 3 times the population norm. Weekend concussions were associated with a one-third further increased risk of suicide compared with weekday concussions (relative risk 1.36, 95% confidence interval 1.14–1.64). The increased risk applied regardless of patients' demographic characteristics, was independent of past psychiatric conditions, became accentuated with time and exceeded the risk among military personnel. Half of these patients had visited a physician in the last week of life.

Interpretation: Adults with a diagnosis of concussion had an increased long-term risk of suicide, particularly after concussions on weekends. Greater attention to the long-term care of patients after a concussion in the community might save lives because deaths from suicide can be prevented.

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Suicide is a leading cause of death in both military and community settings.¹ During 2010, 3951 suicide deaths occurred in Canada² and 38 364 in the United States.³ The frequency of attempted suicide is about 25 times higher, and the financial costs in the US equate to about US\$40 billion annually.⁴ The losses from suicide in Canada are comparable to those in other countries when adjusted for population size.⁵ Suicide deaths can be devastating to surviving family and friends.⁶ Suicide in the community is almost always related to a psychiatric illness (e.g., depression, substance abuse), whereas suicide in the military is sometimes linked to a concussion from combat injury.^{7–10}

Concussion is the most common brain injury in young adults and is defined as a transient disturbance of mental function caused by acute trauma.¹¹ About 4 million concussion cases occur in the US each year, equivalent to a rate of about 1 per 1000 adults annually;¹² direct Canadian data are not available. The majority lead to self-limited symptoms, and only a small proportion have a

protracted course.¹³ However, the frequency of depression after concussion can be high,^{14,15} and traumatic brain injury in the military has been associated with subsequent suicide.^{8,16} Severe head trauma resulting in admission to hospital has also been associated with an increased risk of suicide, whereas mild concussion in ambulatory adults is an uncertain risk factor.^{17–20}

The aim of this study was to determine whether concussion was associated with an increased long-term risk of suicide and, if so, whether the day of the concussion (weekend v. weekday) could be used to identify patients at further increased risk. The severity and mechanism of injury may differ by day of the week because recreational injuries are more common on weekends and occupational injuries are more common on weekdays.^{21–27} The risk of a second concussion, use of protective safeguards, propensity to seek care, subsequent oversight, sense of responsibility and other nuances may also differ for concussions acquired from weekend recreation rather than weekday work.^{28–31} Medical

care on weekends may also be limited because of shortfalls in staffing.³²

Methods

Patient selection

We conducted a longitudinal cohort analysis of adults with a diagnosis of a concussion in Ontario, Canada, from Apr. 1, 1992, to Mar. 31, 2012 (20 yr), based on vital statistics data available through the Office of the Registrar General database.³³ Ontario is Canada's most populous province, with 12 259 564 individuals in 2003 (study midpoint).³⁴ During the study period, the annual suicide rate in Ontario was about 9 per 100 000,³⁵ somewhat lower than the global suicide rate of 11 per 100 000³⁶ and the rate among former military personnel of 14 per 100 000.^{37,38} During the study period, Ontario health insurance covered primary, emergency and hospital care with no out-of-pocket costs to patients.^{39,40} The project was approved by the Research Ethics Board of Sunnybrook Health Sciences Centre; the approval included a waiver of the need for informed consent.

We identified patients with a diagnosis of a concussion by screening physician claims data using the International Classification of Diseases, 9th revision (ICD-9) diagnostic criteria for concussion (code 850) from the Ontario Health Insurance Plan database.^{41,42} This code has been validated with high specificity (99%) and mid-range sensitivity (22%–76%).^{43–45} Patients who were admitted to hospital immediately or within 2 days of injury were excluded because such cases tend to reflect severe brain injury (a known risk factor for suicide) and do not represent ambulatory patients with concussion.^{46,47} Patients under 17 years of age were excluded because most suicide deaths occur in adults.^{48,49} Otherwise, the selection criteria were fully comprehensive and included all patients seeking care whose diagnosis was made by a physician.

Data collection

We distinguished each case as a weekend concussion (midnight Friday to midnight Sunday) or a weekday concussion (remaining 5 days and nights of the week).⁵⁰ Differentiating a weekend from a weekday concussion was based on the date of medical care, which closely corresponds to the date of injury.^{51,52} For patients with multiple concussions, we used the date of the first concussion, such that each person was counted once in the analyses; repeat concussions were tracked for separate secondary analyses. Further data on duration of amnesia, loss of consciousness, mechanism of injury, severity of symptoms, delays in seeking care and

standardized concussion assessment scores were not available.⁵³ Similarly, information was not available on cases that did not lead to medical attention or on whether day of the week was an imperfect proxy for concussion circumstances.

The official demographic registry provided data on patient age, sex and home location (urban or rural).³⁴ Socioeconomic status was based on neighbourhood income quintile and was determined through the validated Statistics Canada algorithm.^{54–56} The health care services databases provided data on hospital admissions, outpatient contacts and diagnoses in the previous year.^{57,58} Prior psychiatric conditions (schizophrenia, depression, bipolar disorder, suicide attempt, anxiety, substance abuse) were determined from physician diagnostic data for the full year before injury.⁵⁹ The available databases contained no information on social stress, life events, employment status, race or ethnicity, sexual orientation, immigration status, borderline personality disorder, childhood abuse, eating disorders, suicidal ideation, novel biomarkers or other suicide risks.^{60–62}

Outcome identification

We determined the cause of death from official death certificates encompassing definite or probable suicide, as investigated by the responsible coroner. All coroners were licensed physicians in Ontario, and suicidal death investigations have an interrater agreement of about 70% in this setting.⁶³ We identified definite cases of suicide by ICD-9 codes (E950–E959) or International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10)⁶⁴ codes (X60–X84) and probable cases of suicide by ICD-9 codes (E980–E987, E989) or ICD-10 codes (Y10–Y32, Y34), as validated in past research.⁶⁵ The database for death certificates has been validated previously and is the official source for vital statistics reporting, as well as the authoritative file for population-based analyses of suicides.^{59,66,67}

For each case, we recorded the forensic certainty and mechanism of suicide from the death certificate. We calculated age at death and elapsed time from index concussion from the same source, coded to the exact day. Similarly, we recorded the time since the last visit with a physician by linking to the physician care database. We also recorded the reason for the last visit, classified as a psychiatric, neurologic, medical or miscellaneous diagnosis along with the physician's specialty.⁶⁸ The available databases did not have information on pathology reports, toxicology reports, psychological scores, presence of a suicide note, litigation involvement, seniority of the investigating coroner or findings from a psychiatric autopsy.⁶⁹

Statistical analysis

In the prespecified primary analysis, we assessed cumulative incidence rates (accounting for censoring and deaths) to estimate the probability of suicide after concussions on weekends and weekdays (Appendix 1, sections 1–5, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.150790/-/DC1). Absolute risks were calculated as deaths per 100 000 persons annually and were also compared with the prevailing suicide rate in the population during the same period.⁷⁰ Cause-specific proportional hazards regression was applied to further quantify differences in suicide risk between the 2 groups before and after adjustment for baseline differences in demographic characteristics, psychiatric diagnoses and history of suicide attempts. All reported *p* values were 2-tailed and were calculated with exact 95% confidence intervals (CIs).

We developed additional statistical models with time-dependent covariables to evaluate patients who had multiple concussions over time (Appendix 1, section 7). For this approach, we applied an accumulating step function so that each concussion was considered a new event and the observed dose–response gradient correlated a patient’s total number of concussions with his or her overall risk of suicide. A 4-week interval was required to identify a subsequent diagnosis as a new concussion (an interval that was defined a priori, because symptoms typically resolve within 1 week and a variable period of rest is recommended afterward).⁷¹ We used the same step function to distinguish each additional concussion according to weekend or weekday occurrence.

Results

A total of 235 110 patients had a diagnosis of a concussion during the 20-year study period. Patient characteristics are detailed in Table 1. About half of the patients were men, the mean age was 41 years, and most were living in an urban location. Most of the patients had no formal medical imaging, additional diagnosed fracture, prior psychiatric diagnosis, prior hospital admission or prior suicide attempt. The baseline frequency of depression and other measured characteristics was not clinically significantly different between those injured on weekends and those injured on weekdays. Anxiety disorder, the single most common prior psychiatric diagnosis, was slightly less frequent among patients injured on weekends. The distribution of characteristics of both groups was generally stable over time.

A total of 667 suicide deaths occurred over a median follow-up of 9.3 years, equivalent to 31 deaths per 100 000 patients annually. Those with a concussion occurring on weekdays

Table 1: Characteristics of patients with diagnosis of concussion in Ontario, Canada

Characteristic	Timing of concussion; no. (%) of patients	
	Weekend <i>n</i> = 39 940	Weekday <i>n</i> = 195 170
Age, yr		
≤ 29	16 088 (40)	67 793 (35)
30–44	9 493 (24)	50 390 (26)
45–59	6 051 (15)	35 727 (18)
≥ 60	8 308 (21)	41 260 (21)
Sex		
Male	22 380 (56)	98 922 (51)
Female	17 560 (44)	96 248 (49)
Income quintile		
Highest	7 141 (18)	37 700 (19)
Next to highest	7 500 (19)	38 148 (20)
Middle	7 799 (20)	38 209 (20)
Next to lowest	8 266 (21)	38 973 (20)
Lowest*	9 234 (23)	42 140 (22)
Home location		
Urban	34 038 (85)	167 975 (86)
Rural*	5 902 (15)	27 195 (14)
Date of enrolment†		
Remote	18 874 (47)	87 386 (45)
Recent	21 066 (53)	107 784 (55)
Initial imaging		
Skull radiography	2 728 (7)	10 678 (5)
Computed tomography	7 364 (18)	22 269 (11)
Magnetic resonance imaging	189 (< 1)	1 654 (1)
Any fracture‡	830 (2)	2 234 (1)
Prior diagnosis§		
Schizophrenia	336 (1)	1 362 (1)
Depression	1 707 (4)	8 515 (4)
Bipolar disorder	603 (2)	2 720 (1)
Substance abuse	1 554 (4)	6 646 (3)
Anxiety disorder	8 223 (21)	44 003 (23)
Any condition¶	9 734 (24)	51 181 (26)
Prior hospital admission§	1 491 (4)	8 157 (4)
Prior suicide attempt§	56 (< 1)	200 (< 1)

*Includes missing values.

†“Remote” denotes years 1992–2001; “recent” denotes years 2002–2012.

‡Any bone (codes 800–829, International Classification of Diseases and Related Health Problems, 9th revision⁴¹).

§Assessed during the year before concussion.

¶Any of the specified psychiatric diagnoses listed above.

accounted for 519 suicides, 1 804 520 patient-years of follow-up and an absolute suicide risk of 29 per 100 000 annually or 3 times the population norm. Those with a concussion occurring on weekends accounted for 148 suicides, 377 115 patient-years of follow-up and an abso-

lute suicide risk of 39 per 100 000 annually or 4 times the population norm. The difference between the 2 groups was equivalent to a one-third increase in suicide risk after a weekend concussion relative to a weekday concussion. Time profiles indicated that the increased suicide risk was distributed evenly over years, with accumulating long-term differences (Figure 1).

The increased risk of suicide after concussions on weekends was evident in comparisons with each individual day of the week (Figure 2). Similarly, all patient subgroups showed an absolute suicide risk above the population norm, all had a further increase in risk after concussions on weekends relative to weekdays, and the findings persisted during both remote and recent eras (Appendix 1, section 6). Patients with a prior suicide attempt had the highest absolute risk and also a further increase after a weekend concussion. Patients with no prior suicide attempt, psychiatric diagnosis or hospital admission ($n = 168\ 188$) had an absolute risk more than twice the population norm and also a further increase after a weekend concussion.

Several other baseline factors were additional independent predictors of the long-term risk of suicide. As expected, suicide risk was associated with male sex, low socioeconomic status and prior psychiatric diagnosis (Table 2). A prior suicide attempt was the single most powerful predictor. Also as expected, a prior diagnosis of substance abuse was another powerful predictor, whereas a diagnosed fracture was not a significant predictor of suicide risk. Each specific psychiatric condition was associated with an increased risk, and no significant anomalies were apparent in analyses that explored post hoc pairwise product interaction terms. Adjustment for all predictors yielded a one-quarter increase in risk of suicide after a weekend concussion (relative risk 1.27, 95% CI 1.06–1.53).

The observed association between concussion and risk of suicide was accentuated in time-dependent statistical models accounting for additional concussions. A total of 24 746 patients had 2 or more concussions and accounted for 205 575 patient-years of follow-up, with 76 suicide deaths. The median interval between consecutive concussions was 214 (interquartile range 69–1018) days. Overall, each additional concussion was associated with a further increase in suicide risk (estimate 1.30, 95% CI 1.12–1.50). Analyzing all concussions in all patients yielded a one-third increase in suicide risk after a concussion on a weekend compared with weekdays (estimate 1.35, 95% CI 1.12–1.63).

We found no significant differences in suicide characteristics after a concussion on a weekend

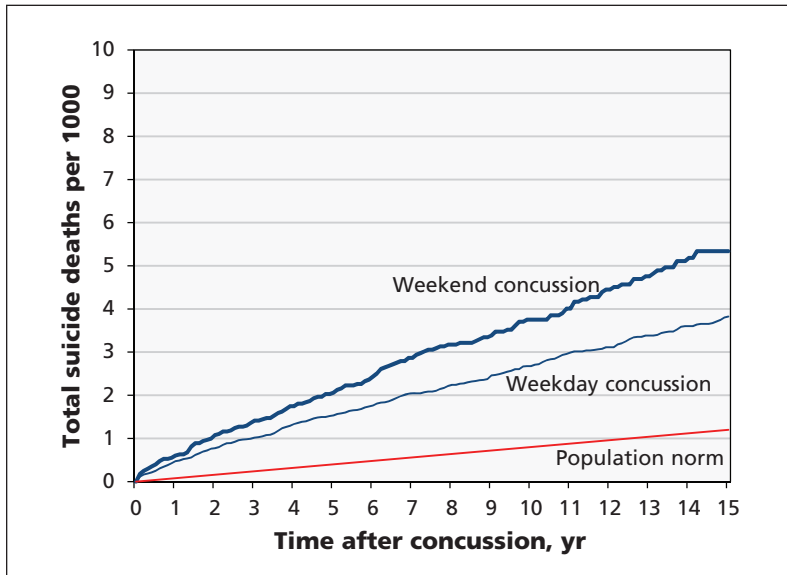


Figure 1: Long-term risk of suicide, shown as the cumulative incidence of suicide after concussion ($p < 0.001$). This p value is based on the log-rank test comparing the weekend concussion group with the weekday concussion group; p values comparing study patients with the population norm were more extreme and are not reported. The main findings showed progressive differences in suicide risk after the initial concussion.

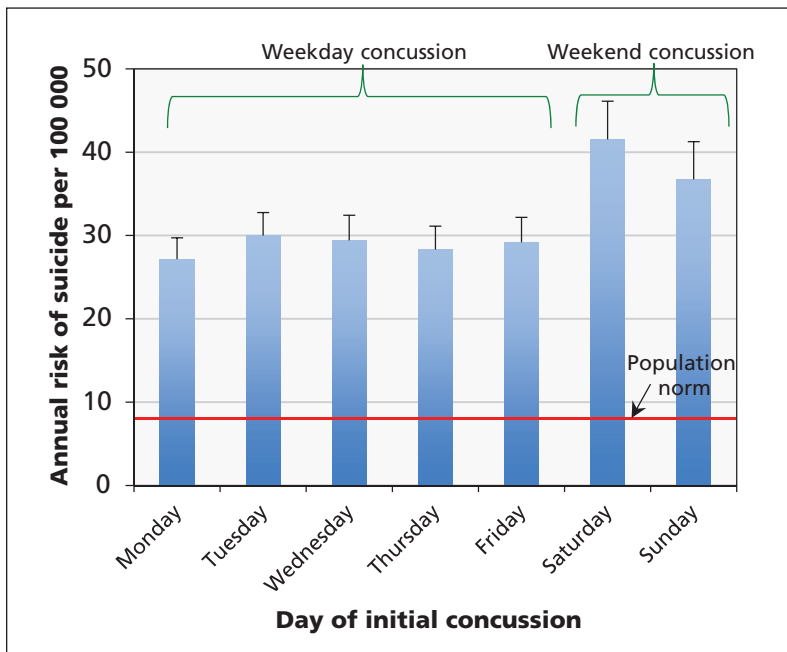


Figure 2: Risk of suicide by day of initial concussion. Error bars denote the upper standard error of the estimates. Horizontal red line shows the population norm of 9 per 100 000. The main findings showed a consistent increase in the long-term risk of suicide after concussion on a weekday, with a further increase after concussion on a weekend.

compared with a weekday. The mean time from concussion to suicide was 5.7 years (Table 3). In accordance with legal criteria, three-quarters of the cases were determined as definite suicide and the remainder as probable suicide. Poisoning was the most common mechanism, accounting for almost half of the cases in both groups. Asphyxiation was the second most common mechanism, accounting for about a third of the cases in both groups. Most of the patients had visited a physician in the month before death, primary care physicians accounted for the majority of these visits, and a psychiatric disorder was the responsible diagnosis for a minority of the visits.

Interpretation

We studied data for about a quarter million adults to assess the risk of suicide after a concussion. We found that the long-term risk of suicide among those with a concussion was 3 times the population norm and was even higher if the concussion occurred on a weekend. The increased risk applied regardless of demographic characteristics, was independent of past psychiatric conditions, became accentuated with time, followed a dose–response gradient and was not as high as the risk associated with past suicide attempts. About half of the patients had visited a physician in the last week of life, typically for a diagnosis unrelated to mental illness. The absolute risk was equal to about 470 suicide deaths that might not have occurred if the prevailing risks had matched the population norm (Appendix 1, section 9).

Our findings are congruent with the results of past studies indicating that suicide attempts are the single most important long-term predictor of subsequent risk of suicide.^{72,73} Additional long-term predictors confirmed in this analysis included male sex, low socioeconomic status and prior psychiatric history.^{74,75} Past studies have cautioned that individual risk factors have low accuracy for predicting individual events.^{76,77} No past study, to our knowledge, has focused on concussions and tested the potential difference between weekends and weekdays. Moreover, the increased long-term risk of suicide observed in this study persisted among those who had no psychiatric risk factors and was distinctly larger than among patients after an ankle sprain (Appendix 1, section 8).

Our findings also support past research on differing theories of suicide.^{78–80} Past studies have suggested that a concussion can cause lasting deficits through changes in physiology (e.g., disrupted serotonin pathways), mood (e.g., post-traumatic stress disorder) or behaviour (e.g., disinhibition with impulsivity).^{81–84} Cognitive dissonance could also lead patients and clinicians

to attribute injuries after weekend recreation to misadventure, whereas injuries following weekday occupation might be attributed to the employer.^{85–87} With hindsight, a difference in activity restriction or cognitive dissonance might arise if the injury event was self-initiated.^{88,89} Further research is needed to address these issues; in the interim, our findings suggest that a history of concussion may be relevant when assessing a patient's suicide risk.

Limitations

An alternative interpretation of our findings is unmeasured confounding. A concussion might indicate a latent predisposition toward suicide before the injury or worsening neurodegenerative deficits that precipitated the injury.^{90,91} Exploring these mechanisms is difficult because of the fallibility of gauging comorbid illness, concussion severity, chronic traumatic encephalopathy, long-term risk of suicide and the exact time of a concussion.⁹² Such mechanisms might fully explain our findings, including the observed increased risk that expanded for years after injury, did not change the mechanism of suicide and occurred despite medical care (Appendix 1, section 10). Regardless of interpretation, these findings sug-

Table 2: Long-term predictors of suicide after concussion*

Predictor	RR (95% CI)	
	Univariable analysis†	Multivariable analysis‡
Weekend concussion	1.36 (1.14–1.64)	1.27 (1.06–1.53)
Age, per yr older	1.00 (1.00–1.00)	NA
Sex, male	2.28 (1.92–2.70)	2.47 (2.08–2.94)
Income, low	1.68 (1.33–2.13)	1.30 (1.02–1.65)
Home, rural	0.97 (0.78–1.20)	NA
Enrolment, recent§	0.96 (0.95–0.98)	0.96 (0.94–0.97)
Imaging¶	1.38 (1.15–1.66)	1.31 (1.09–1.57)
Fracture	1.09 (0.59–2.04)	NA
Schizophrenia	10.78 (7.89–14.73)	2.38 (1.68–3.37)
Depression	4.32 (3.49–5.35)	1.65 (1.30–2.11)
Bipolar disorder	7.03 (5.31–9.32)	1.96 (1.43–2.68)
Substance abuse	8.43 (7.04–10.10)	3.60 (2.94–4.41)
Anxiety disorder	3.98 (3.42–4.64)	3.04 (2.57–3.60)
Prior hospital admission	2.28 (1.53–3.40)	1.40 (0.89–2.21)
Prior suicide attempt	38.83 (23.94–62.99)	5.65 (3.26–9.81)

Note: CI = confidence interval, NA = not applicable, RR = relative risk.
 *Results from proportional hazards analysis, with weekdays defined as referent.
 †Basic comparison with no adjustments for other baseline differences.
 ‡Adjusted comparison accounting for other baseline differences in demographic characteristics, psychiatric diagnoses and history of suicide attempts.
 §“Recent” denotes years 2002–2012 (years 1992–2001 denoted as “remote”).
 ¶Includes skull radiography, computed tomography and magnetic resonance imaging.

gest that an association between concussion and suicide is not confined to the military.

Our study also highlights the modest ability of any one factor to predict suicide because most patients do not die from suicide (Appendix 1, section 11). Furthermore, studies of suicide are prone to detection bias because social stigma leads analyses to underestimate total counts.^{93,94} Each case is different, such that mathematical models are fallible through a lack of myriad relevant data, such as alcohol consumption and suicidal ideation.⁹⁵ Long-term predictions and gen-

eralizability are also problematic because of the network of intervening factors and shifting definitions of concussion.^{47,96,97} Some patients with concussion receive care that may mitigate the risk of suicide, such as antidepressant medication;^{98,99} however, our study lacked data on such care, which remains a topic for future research.

Conclusion

Concussion differs in 3 important ways from other risk factors for suicide. First, concussions are sometimes preventable through adequate training, the minimizing of distractions, avoidance of alcohol, use of protective gear and other safety basics.¹⁰⁰ Second, concussions are easily neglected under a popular belief that the neurologic symptoms have an obvious cause, will resolve quickly, leave nothing visible on medical imaging and do not require follow-up.^{101,102} Third, concussions are rarely deemed relevant for consideration by psychiatrists or other physicians when eliciting a patient's history.^{103,104} Greater attention to the long-term implications of a concussion in community settings might save lives because deaths from suicide can be prevented.^{105,106}

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Table 3: Distinguishing circumstances of suicide

Variable	Timing of concussion; no. (%) of suicide deaths*	
	Weekend n = 148	Weekday n = 519
Determination of death as definite suicide	107 (72)	393 (76)
Time since concussion, yr, mean ± SD	5.6 ± 4.5	5.8 ± 4.8
Age at death, yr, mean ± SD	43.6 ± 14.1	44.1 ± 14.1
Mechanism of death		
Poisoning	66 (45)	227 (44)
Asphyxiation†	51 (34)	158 (30)
Violence‡	18 (12)	80 (15)
Jumping	8 (5)	39 (8)
Other	5 (3)	15 (3)
Recent physician visit		
< 1 wk	75 (51)	240 (46)
< 1 mo	114 (77)	370 (71)
< 1 yr	142 (96)	494 (95)
Physician specialty		
Psychiatry	12 (8)	55 (11)
Neurology§	7 (5)	16 (3)
Internal medicine	16 (11)	38 (7)
Family medicine	90 (61)	334 (64)
Other¶	17 (11)	51 (10)
Recent diagnosis		
Psychiatric**	40 (27)	166 (32)
Neurologic††	4 (3)	25 (5)
Medical‡‡	40 (27)	139 (27)
Miscellaneous§§	64 (43)	189 (36)

Note: SD = standard deviation.
 *Unless indicated otherwise.
 †Asphyxiation includes hanging, strangulation, drowning and suffocation.
 ‡Violence includes firearms, explosives, crashes and stabbings.
 §Includes neurosurgery, anesthesiology, ophthalmology and otolaryngology.
 ¶Includes surgery, obstetrics, gynecology and medical imaging.
 **Codes 295 to 316 (International Classification of Diseases and Related Health Problems, 9th revision⁴¹ [ICD-9]).
 ††ICD-9 codes 290 to 389, except psychiatric.
 ‡‡ICD-9 codes 001 to 779, except psychiatric or neurologic.
 §§ICD-9 codes 780 to 999 or missing.

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