TABLE 10.1 TBI and Mortality

Reference	Study Design	Population	Type of TBI	Health Outcomes or Outcome Measures	Results	Adjustments	Comments or Limitations
Baguley et al., 2000	Cohort composed of clinical case series	Patients with TBI admitted to Brain Injury Rehabilitation Service, Westmead Hospital, New South Wales, Australia, 1986–1996; cases had survived through admission into rehabilitation facility; comparison group: expected mortality in age- and sex-matched Australian population in 1997	Severe; 97% closed, 3% penetrating	Mortality by August 1997 (mean, 5 years after trauma; range, 8 mo–11 years after trauma); ascertained by New South Wales vital-statistics search	476 patients, mean duration of followup 64 mo; 97% closed head injury, 3% penetrating head injury; 62% MVC, 21% falls or hit by object, 12% assault, 4% sports-related 27 of 476 (5.7%; 95% CI, 0.037–0.083) dead (median, 17 mo after trauma; range, 45 day–9 years 2 mo after trauma); expected mortality rate, 1.5% (CI, 0.006–0.03) ($p<0.001$ by Fisher's exact test) Contributing factors: low FAM on discharge ($p <$	None	Missing FAM, preinjury information on substance abuse, psychiatric history from patients admitted before 1990 on 52% of the deceased, 22% of the living; no multivariate analysis

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					0.001), being male (p = 0.078), greater age (p = 0.055), prior psychiatric morbidity (p = 0.064), but not prior substance abuse (p = 0.308) by chi2 or t test Cause of death: cardiorespiratory arrest (30%), infection (22%)		
Brown et al., 2004	Population-based retrospective cohort from Rochester Epidemiology Project	Any Olmsted County, MN, resident with medically attended TBI, 1985–1999 (N = 45,831); random 15.7% sample of TBI patients (N = 7,175) reviewed; 1,448 met inclusion criteria; comparison group: age- and	Documented concussion with LOC; PTA; neurologic signs of brain injury and/or intracerebral, subdural, or epidural hematoma; cerebral hemorrhage or contusion; brain stem	Vital status through 2002 from medical records, state death tapes	Age 35.3 years for moderate–severe, 26.8 years for mild; mean followup, 7.4 years Mortality in moderate–severe: 68 deaths in 164 cases; overall risk of death increased compared with expected, RR, 5.29 (95% CI, 4.11–6.71) by	Age, sex for mortality analysis; age, sex, year of TBI with Cox proportional-hazards model for comparison of moderate–severe vs mild	Unique database on medical care of county's entire population; cohort not generalizable beyond Olmsted County—few minority-group members (96% white), all care in

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		sex-specific 1990 white Minnesotans	injury; penetrating head injury; skull fracture; or postconcussive syndrome Moderate or severe (11%): skull fracture, intracranial hematoma, brain contusion, penetrating head injury, brain stem injury, or severe complications (neurosurgery, CNS infection, subarachnoid hemorrhage, hydrocephaly, CSF leak)		long-rank statistic; 30-day CFR, 29.3% by Kaplan–Meier, risk increased compared with expected, RR, 5.29 (95% CI, 4.11–6.71); 14 deaths in those surviving≥6 mo, no increase in risk, RR 1.10 (95% CI, 0.60–1.85) Mortality in mild: 78 deaths in 1,284 cases; overall risk of death increased compared with expected, RR, 1.33 (95% CI, 1.05–1.65); 9 deaths in first 6 mo (CFR, 0.2%), no difference from expected 69 deaths in those surviving 6 mo;		only 2 institutions

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			Mild (89%): LOC, PTA, postconcussive symptoms, focal neurologic signs		risk of death not increased compared with expected, RR, 1.18 (95% CI, 0.92–1.49) Comparison of moderate–severe with mild: risk of death increased in first 6 mo, RH, 5.18 (95% CI, 3.65–7.30) by Cox proportional-hazards model; no difference≥6 mo, RH, 1.04 (95% CI, 0.57–1.88)		
Corkin et al., 1984	Prospective cohort (World War II veterans assembled at NYU by Teuber in 1948)	All WWII veterans with penetrating head injury from Teuber series (n = 190); excludes few with nonpenetrating head injury; 106 WWII controls with peripheral	Penetrating, at least 3 years after trauma	Mortality to 5/1/1983 as function of various factors	Mortality: 54 of 190 (28.4%) with penetrating head injury dead vs 18 of 106 (17.0%), significant difference by Kaplan–Meier (p = 0.03); those with PT epilepsy (N = 82) more likely to be dead	Cox proportional regression adjusted for age at injury, years of education, difference in AGCT (preinjury vs 10 years	Vital status could not be determined on only one subject (treated as alive); no cause-of-death data collected

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		nerve injuries matched for age, education, preinjury AGCT (85% of controls in Teuber series with such injuries)			than those without (N = 91) or controls (p = 0.0002); PT epilepsy (p = 0.003), lower education (p = 0.02) associated with death by Cox	after trauma)	
Harrison-Felix et al., 2004	Retrospective cohort from 15 TBIMS centers	2,178 TBI patients ≥16 years old completing inpatient rehabilitation in 1988–2000; sample is 2,140 who survived >1 year after trauma; comparison group: US age- and sex-specific mortality in 1994	Age 37.4 years, 76% male, 60% white Cause of injury: MVC, 62%; violence, 20%; falls, 16%; other, 2% Severity: 37% severe (24-h max GCS ≤ 8) ALOS: 21 days acute care, 30 days	Mortality from SSA Death Index through 2001	Mortality: 123 of 2,140; median, 2 years; overall, SMR, 2.00 (95% CI, 1.69–2.31); <1 year after trauma, 38 deaths; ≥1 year after trauma, 123 deaths, SMR, 1.95 (95% CI, 1.61–2.29); life expectancy, average reduction, 7 years, depending on age at injury, sex, race, with range 5–9 years Risk factors:	Age, sex, race in determining SMRs from federal statistics for 2000; Cox proportional hazards for those surviving >1 year	Maximum followup only 13 years, average 3.1 years from 1 year after trauma; 38% loss to followup; two of 17 centers did not participate, so sample less representative

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			acute rehabilitation		higher age, unemployment at time of injury, higher DRS score at discharge		
Lewin et al., 1979	Retrospective cohort (same population studied in book by AH Robert, 1979, with same results, but also mentioned suicide as cause of increased deaths) (Cause-of-death comparison)	7,000 consecutive head injured patients admitted into John Radcliffe Infirmary, Oxford, 10–24 years earlier (1955–1969); of these, 479 amnesic or unconscious >1 week; additional selected series: 64 cases unconscious >1 mo admitted to this or other facility 3–25 year earlier (including 24 from first set); causes of death	Severe in large part closed, but complicated by compression or penetration (traumatic or surgical for internal decompression) for 77 and 14, respectively, of 331 survivors	Vital status; for 178 (consecutive series), 28 (selected series) who died, cause of death; for 331 survivors, neurologic examination (all), test of cognitive function (217)	Overall mortality, 178 of 469 (38%) Life expectancy for four neurophysical-disability patterns—"decerebrate dementia": most <1 year, one >10 years; "athetoid pseudobulbar": reduced only by epilepsy, drowning, inhalation of food, suicide; "brain-stem cerebellar" or "minor hemiparetic": reduction of <5 years	Age, maximum central neural disability score, maximum mental disability score, duration of PTA for model	Only 2% loss to followup; developed model for predicting long-term outcome on basis of age at injury, worst category of mental and neurophysical disability, length of PT amnesia in selected series

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		in 78 patients discharged from initial hospitalization alive were compared with causes of death in general population of England, Wales in 1960 (not age- or sex-adjusted)			Cause of death among those discharged compared with general public: meningitis, $p < 0.001$; epilepsy, $p < 0.001$; drowning, $p < 0.001$; respiratory, $p < 0.005$ Neurologic outcomes at 10 years (consecutive series): 11 (4%) totally disabled; 66 (14%) severely disabled, precluding normal social, occupational life; 214 (46%) recovered; 178 (38%) dead Hospitalization:		

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					continuing need discussed but not quantified		
Ratcliff et al., 2005	Retrospective cohort	640 patients ≥14 years old with moderate to severe TBIs discharged 8–24 years after trauma from Pittsburgh, PA, rehabilitation center, 1974–1984, 1988, 1989; comparison group from Pennsylvania vital-statistics tables	Head injury identified by ICD-8 and -9 codes 800–801-9, 803–804.9, 850–854.9, excluding comorbid spine injury Cause of injury: MVC, 66%; violence, 2%; falls, 16%; other, 15% Moderate to severe cases (range, 4–54) retained, severity based on ICD at discharge as converted	Mortality through 1997	Overall mortality: 128 (19.7%) deaths; SMR, 2.78; $p < 0.0001$ by Poisson regression Any preinjury social or behavioral problem: SMR, 5.82, $p < 0.0001$ Alcohol abuse: SMR, 6.10; $p < 0.0001$ Substance abuse: SMR, 8.00; $p < 0.0001$ Other personal or social problems: SMR, 7.03; $p < 0.0001$ Functional	Age at injury, sex, education, marital status, race, cause of injury, severity of injury	Subjects outside range of interest for age at time of injury: <18 years, 19%; ≥60 years, 13% Followup, 8–24 year after trauma; excluded 1985–1987 to keep sample size smaller, manageable; 6.5% could not be traced (assumed alive); univariate analysis of numerous variables, but final multivariate

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			into ISS with range 0–75 (MacKenzie et al., 1989; Kingma et al., 1992).		limitations at discharge (seven items with three levels): Bathing, p = 0.01; grooming, p = 0.002; dressing, p = 0.011; eating, p = 0.003; bed-to-chair, p = 0.035; toilet use, p = 0.017; walking across room, p = 0.019; summation partitioned into four levels, p = 0.008 Y ears after discharge, severity of injury not significant; final stepwise regression model if no preinjury behavioral problem or functional limitation at discharge, SMR,		model contained only preinjury behavioral problems, grooming or eating problems; importance of preinjury factors suggests that a property of people experiencing TBI, rather than TBI itself, may increase mortality

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Rish et al., 1983	Prospective cohort (registry established 1976–1980 by MFUA, WF Caveness)	1,127 male Vietnam veterans alive 1 week after trauma; comparison group: age- and sex-matched from North American actuarial data (American Council of Life Insurance)	Penetrating cerebrocranial wounds	Mortality 15 years after trauma	1.69 Overall mortality: 90 of 1127 (8%), 46 in first year after trauma, 32 in first 3 mo, 16 in first month; compared with North American males, mortality increased up to 13 years after trauma (primarily 1–2 years after trauma), near actuarial rates at 14–15 years after trauma Cause of death: after second year, same as general population plus continuing losses due to coma sequelae, seizures and brain abscesses; coma (initial level of consciousness and duration)	Age and sex	Exclusively penetrating injuries, whose consequences may differ from those of concussive injuries

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					most predictive of mortality, not PT seizures 26 of 1,050 (2.6%) deaths among those who were discharged to self care vs 67 of 80 (84%) of those who required continued hospitalization		
Selassie et al., 2005		3,679 patients ≥15 years old with TBIs discharged from 62 acute-care nonfederal hospitals in South Carolina in 1999–2001, with selection from 6,583 eligible stratified on severity, hospital size; comparison group: rates,	AIS scores of severity converted from ICD-9-CM codes at discharge; mild, AIS ≤2); moderate, AIS 3; severe, AIS ≥4	Mortality <15 mo after discharge from acute care	Mortality <15 mo of discharge: 308 deaths; median, 93 days; range, 1–453 days; survival curves differ by severity, p < 0.0001 Overall SMR, 7.1 (95% CI, 6.3–7.9); cancer (n = 31), SMR, 3.1 (95% CI, 2.1–4.2); heart disease (n = 50), SMR, 3.7 (95% CI, 2.8–	Age, sex, race for SMRs based on US population; Cox proportiona l- hazards model	Some subjects <18, >60 years old Focus on only 15 mo after discharge 1,544 (42%) refused or not located Death certificates obtained for 94% of known deaths

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		causes of death in US population in 2000			4.8); unintentional injury (n = 61), SMR, 36.3 (95% CI, 27.8–46.0); cerebrovascular disease (n = 18), SMR, 11.7 (95% CI, 8.2–15.9) Risk of death associated with age, number of comorbidities, AIS ≥ 4, Medicare, care in nontrauma center		74% of injury-related deaths related to original TBI Did not find excess deaths associated with seizures, respiratory infections, choking and suffocation, suicide
Shavelle et al., 2000	Retrospective cohort	2,629 people with TBI >15 years old, in 1988–1997, receiving services from California Department of Developmental Services (implying severe disability) and survived ≥1	TBI by ICD-9 codes 800–804, 850–854	Mortality as recorded in state vital statistics	Mortality ratio: overall, 277%; nonambulatory patients, 660%; partially ambulatory, 196%; ambulatory, 180%	Stratified by ambulation status	Patients with severe disabilities only, not analogous to incident cohort

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		year; comparator: 1990s US life tables by sex,					
Walker et al., 1971	Cohort	1,000 Bavarian head injured men from WWI randomly selected from among 5,500 cases in head injury center in 1916–1927 with "sufficient information for analysis" of nature of injury; 1,000 unwounded Bavarian WWI veterans on pension lists for receiving medal; all born 1880–1900; final, 555 cases, 563 controls	Mixed severity, type (nonpenetrating slightly >50%)	Mortality to 1965 by life-table analysis; epilepsy at "some time after injury" (first event for most within year of injury, but persisted for most); broad classifications of cause of death	5-year bands of age-specific life expectancies calculated for >35 years; 73% of cases, 80% of controls alive at age 65 years; across all age bands, life expectancy was increasingly lower for control veterans, head injured without epilepsy, head injured with epilepsy in comparison with general population; aside from sequelae of injuries, no cause of death stood out for head injured	PT epilepsy; bracketing estimates derived by assuming that those with unknown vital status were all alive or were random sample of population	50 years of followup; statistics rather primitive; biases likely in selection of study population (for example, representativeness of cases at center of all head injured and of those with sufficient information of all cases; controls all received medals); vital status of 400 of 1,000 not attainable, but same number found for

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							controls;.for both groups, date, cause of death found for 56%, but vital status unknown for about one-fourth
Weiss et al., 1982	Cohort	1,010 head injured Bavarian men from WWI; 1,000 unwounded Bavarian WWI veterans; final, 647 cases, 616 controls		Mortality to 1972 by life-table analysis; cause of death.	Mortality: overall, 497 of 647 with TBI vs 483 of 616 controls; ages 35–70 years, brain-injured vs control, no difference; wound ≥3 cm vs 0–3 cm, ns increase; coma ≥1 day vs <1day, no difference; PT seizures vs no, increase maximal at ages 50–65 years; PT seizures vs control, increase (p = 0.01) Cause of death:	None	If this sample was first defined in or before 1930, it has proved to be effectively a prospective cohort with 60 years of followup

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					TBI vs control, cerebrovascular ($p = 0.01$), <60 years ($p = 0.015$), ≥60 years ($p = 0.04$), not related to three measures of severity; cardiovascular–renal, no difference		

NOTE: AGCT = Army General Classification Test, AIS = Abbreviated Injury Scale, ALOS = average length of stay, CFR = case-fatality rate, CI = confidence interval, CNS = central nervous system, CSF = cerebrospinal fluid, CT = computed tomography, FAM = Functional Assessment Measure, GCS = Glasgow Coma Scale, GOS = Glasgow Outcome Score, ICD = International Classification of Diseases, LOC = loss of consciousness, MFUA = Medical Follow-Up Agency, MVC = motor-vehicle crash, NYU = New York University, PT = posttrauma, PTA = posttraumatic amnesia, RH = relative hazards, RR = relative risk, SMR = standardized mortality ratio, SSA = Social Security Administration, TBI = traumatic brain injury. WWI = World War I.