

# Traumatic Brain Injury and Commercial Motor Vehicle Driver Safety

## Findings of Evidence Report

Developed by  
James Reston, PhD, MPH



# Traumatic Brain Injury (TBI) and Potential Crash Risk

- Potential risk of a motor vehicle crash among individuals with TBI:
  - TBI severity varies from mild to moderate or severe
  - Does severity or other factors influence crash risk?
  - Can treatment reduce crash risk?



**Federal Motor Carrier Safety Administration**



# Key Questions

- Key Question 1

- What is the impact of traumatic brain injury on crash risk/driving performance?

- Key Question 2

- What factors associated with traumatic brain injury are predictive of increased crash risk or poor driving performance?



**Federal Motor Carrier Safety Administration**



# Key Questions

- Key Question 3

- What is the impact of rehabilitation programs on crash risk/driving performance among individuals with a traumatic brain injury?

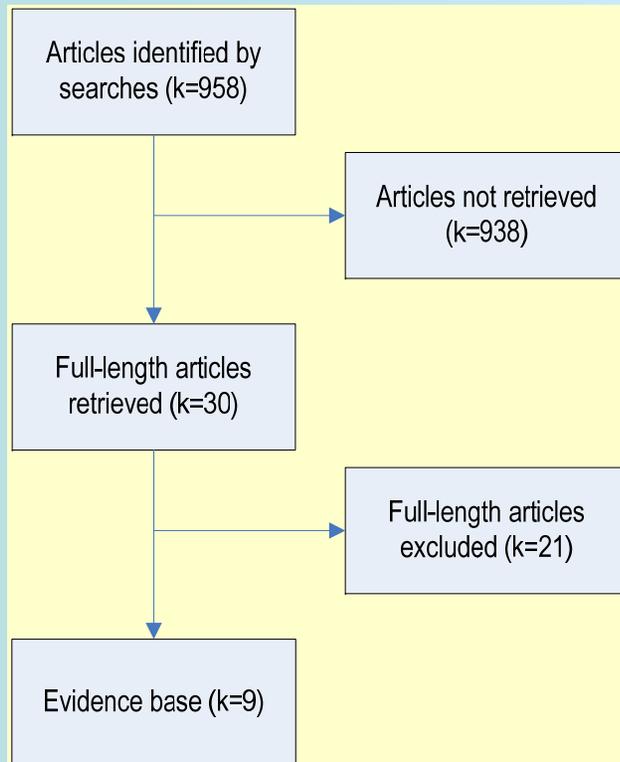
- Key Question 4

- What is the likelihood of a future seizure among individuals with a traumatic brain injury who did not experience a seizure at the time of the injury?



**Federal Motor Carrier Safety Administration**

# Key Question 1: TBI and Crash Risk



- 9 studies included
- No CMV drivers
- All Cohort studies
- Quality = 6 moderate, 3 low

**Federal Motor Carrier Safety Administration**

# Key Question 1: Study Characteristics

Reference	Year	Severity of TBI	Driving exposure controlled for?	Other factors controlled for	Outcome(s) self-reported?
<b>Studies of TBI and Crash Risk</b>					
Schanke et al.	2008	NR	Yes	Age, gender	Yes
Formisano et al.	2005	Severe	Partly (5 year period, but mileage not controlled for)	Age, gender	Yes
Schneider and Gouvier	2005	Mild (90%) Moderate (10%)	Partly (2-year period, but mileage not controlled for)	Age, gender, race	Yes
Schultheis et al.	2002	NR	Partly (5-year period, but mileage not controlled for)	Age, education, years of driving experience	Yes
Haselkorn et al.	1998	NR	Partly (2-year period, but mileage not controlled for)	Age, gender, zip code	No, state records
<b>Studies of TBI and Driving Performance (on-road or simulated)</b>					
Cyr et al.	2008	Moderate (n = 2) or Severe (n = 15)	NR	Age, gender	No
Lew et al.	2005	Moderate or severe	NR	Age and gender similar, not perfectly matched	No
Korteling	1990	Moderate or severe	Yes	Age, gender, education	No
Kewman et al.	1985	Severe	No	None	No
NR: Not reported					



# **Key Question 1: TBI and Crash Risk**

- Generalizability of these studies to CMV drivers may be limited.
- CMV drivers have greater risk exposure than non-CMV drivers.
- Women are overrepresented relative to the CMV driver population.
- CMV drivers are under more pressure to drive even if they are experiencing symptoms of TBI.



**Federal Motor Carrier Safety Administration**



# Key Question 1: TBI and Crash Risk

- Crash Studies
  - All 5 studies compared drivers with TBI to a control population without TBI.
  - Results from 4 out of 5 studies that reported crash rate ratios (or allowed calculation of crash rate ratios) were combined in a meta-analysis.



**Federal Motor Carrier Safety Administration**

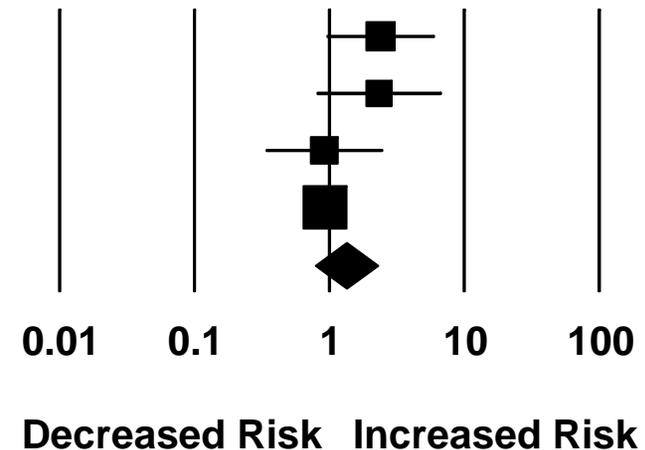
# Key Question 1: TBI and Crash Risk - Results

## Study name

## Statistics for each study

## Rate ratio and 95% CI

	Rate ratio	Lower limit	Upper limit	Z-Value	p-Value
Schanke	2.400	0.944	6.102	1.839	0.066
Formisano	2.340	0.795	6.892	1.543	0.123
Schultheis	0.917	0.333	2.522	-0.168	0.866
Haselkorn	0.929	0.638	1.354	-0.381	0.703
<b>Summary</b>	<b>1.320</b>	<b>0.773</b>	<b>2.252</b>	<b>1.018</b>	<b>0.309</b>



**Federal Motor Carrier Safety Administration**

# Key Question 1: TBI and Driving Performance - Results

- Driving Performance Studies (On-road or Simulated)
  - Two studies evaluated driving simulator performance.
  - Two studies evaluated on-road driving performance.
  - Because each study used different performance measures, no meta-analysis was attempted.

**Federal Motor Carrier Safety Administration**

# Key Question 1: TBI and Driving Performance - Results

- Driving Simulator Studies
  - Individuals with TBI showed significantly poorer performance than unimpaired individuals on various measures, including number of simulated crashes and violations and hits on divided attention tasks.



**Federal Motor Carrier Safety Administration**

# Key Question 1: TBI and Driving Performance - Results

- On-road Driving Performance Studies
  - One study tested specific performance tasks, found significantly poorer performance by drivers with TBI on several measures, including major errors, composite score, and driver educator's score, compared to unimpaired controls.
  - One study evaluated specific driving tasks involved in platoon car following, found significantly poorer performance by drivers with TBI on brake reaction time, delay time, and speed reproduction, compared to unimpaired controls.

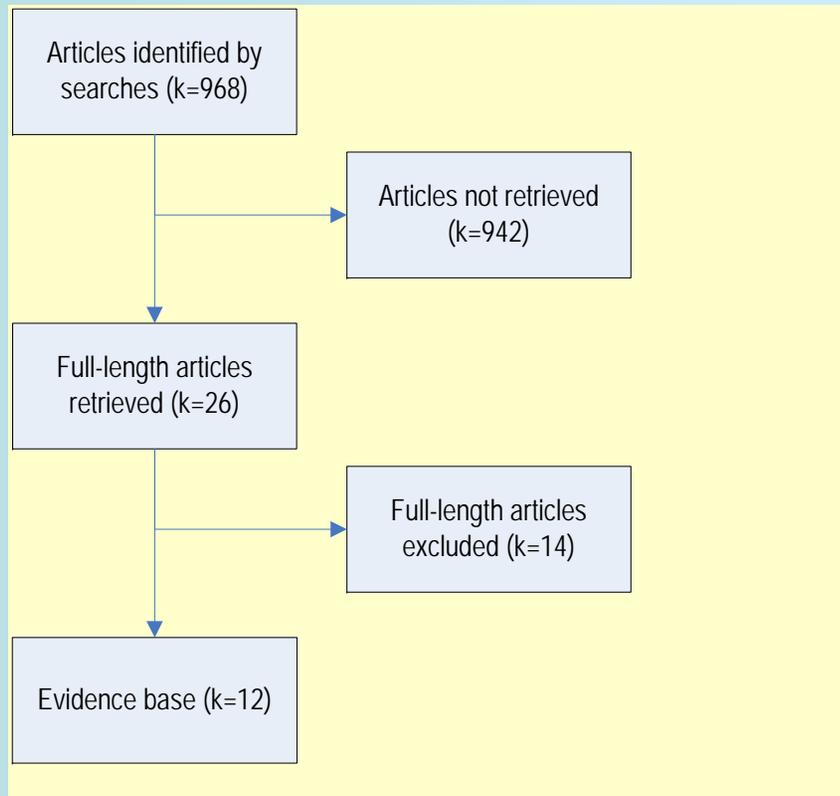
**Federal Motor Carrier Safety Administration**

# **Key Question 1: TBI and Crash Risk/ Driving Performance - Summary**

- **The available evidence is insufficient to determine whether crash risk is elevated for drivers with TBI compared to uninjured controls. However, driving performance as measured by on-road driving tests and driving simulators was significantly impaired among individuals with TBI compared to uninjured controls. (Strength of Evidence: Moderate)**

**Federal Motor Carrier Safety Administration**

# Key Question 2: Factors Associated with TBI and Crash Risk



- 12 studies included
- No CMV drivers
- All cohort studies
- Quality = 8 moderate, 4 low

# Key Question 2: Study Characteristics

Reference	Year	Severity of TBI	Factors evaluated for association with outcomes	Relevant outcomes	Outcome(s) self-reported?
<b>Studies of factors associated with crash/driving offenses</b>					
Rapport et al.	2008	Mild (21.1%) Moderate or severe (76.9%)	Years post-injury, amount of driving, neuropsychologic functioning, self-rating of driving ability	Crash, traffic tickets, near-miss accidents	Yes
Formisano et al.	2005	Severe	Glasgow outcome scale (GOS) scores	Crash	Yes
Pietrapiana et al.	2005	Severe	Age at interview, age at TBI, year post-injury, education, age at licence achievement, years of driving pre-TBI, accidents and violations pre-TBI, neurocognitive measures	Crash or traffic violation	Yes
Schneider and Gouvier	2005	Mild (90%) Moderate (10%)	Various neurocognitive measures	Crash	Yes
Coleman et al.	2002	Moderate or severe	Years post-injury, pre-injury driving record, various neurocognitive measures	Crash or traffic conviction	No
<b>Studies of factors associated with road test outcomes</b>					
Bouillon et al.	2006	NR	Age, gender, comprehension, expression, and time since diagnosis, various neurocognitive measures	On-road test outcome	No
Novack et al.	2006	Severe (72%) Moderate (18%)	Age, brake reaction time, various neurocognitive measures	On-road test outcome	No
Radford et al.	2004	NR	Various neurocognitive measures	On-road test outcome	No
Strypstein et al.	2001	NR	Various neurocognitive measures	Fitness to drive decision	No
Korteling	1996	NR, but most appear to be severe	Age, coma duration, driving experience, additional lessons	Driving fitness	No
Brooke et al.	1992	NR	Various neurocognitive measures	Driving fitness	No
Gouvier et al.	1989	NR, but most appear to be severe	Various neurocognitive measures	Closed-course driving test	No
NR: Not reported					

# Key Question 2: Factors Associated with TBI and Crash Risk

- Studies of Factors Associated with Crash/Driving Offenses
  - All 5 studies compared drivers with TBI with crash or driving offenses to drivers with TBI but no driving incidents.
  - 4 out of 5 studies used multiple regression models to identify statistically significant predictor variables.



**Federal Motor Carrier Safety Administration**

# **Key Question 2: Factors Associated with TBI and Crash Risk - Results**

- Studies of Factors Associated with Crash/Driving Offenses
  - Conflicting evidence on neuropsychological function test scores, but different studies evaluated different tests.
  - Factors unrelated to TBI (e.g. years post-injury, pre-TBI driving record) seemed to be better predictors of crash or driving offenses than TBI-related variables.



**Federal Motor Carrier Safety Administration**

# **Key Question 2: Factors Associated with TBI and Driving Performance**

- Studies of Factors Associated with Driving Performance
  - 7 studies evaluated association between potential predictor variables and road test or closed-course driving outcomes.
  - 6 out of 7 studies used multiple regression models to identify statistically significant predictor variables.

**Federal Motor Carrier Safety Administration**

# **Key Question 2: Factors Associated with TBI and Driving Performance - Results**

- Studies of Factors Associated with Driving Performance
  - Overall, studies suggest that poorer scores on neuropsychological tests (indicating reduced cognitive function) may be associated with road test failure for patients with TBI.
  - High variability among studies regarding which neuropsychological tests were used.



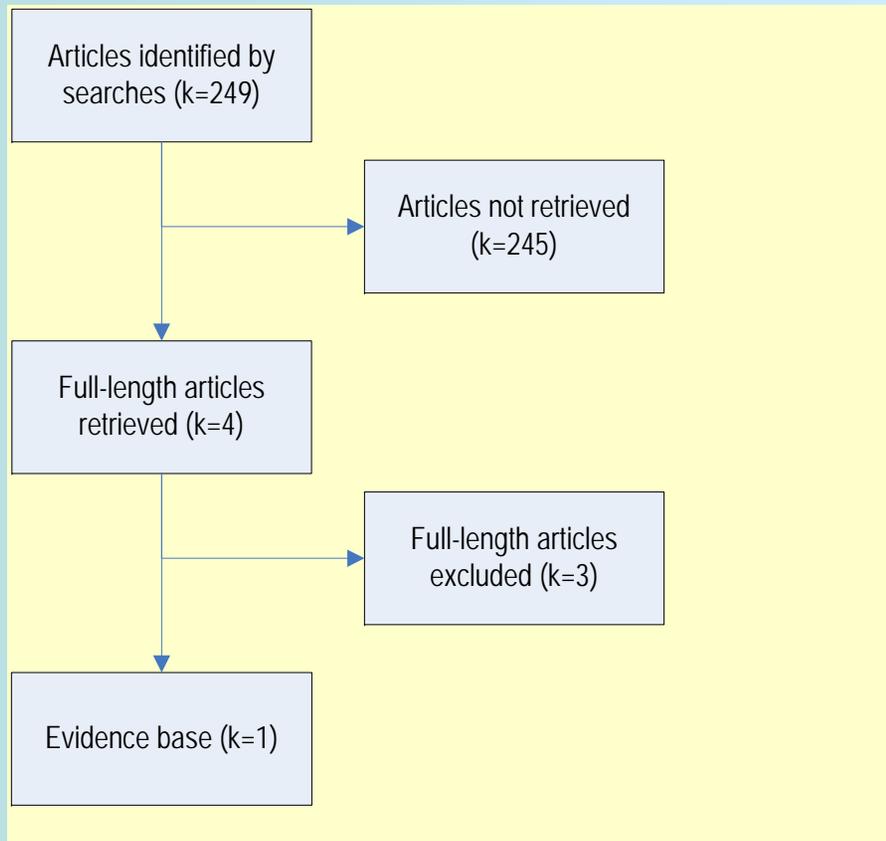
**Federal Motor Carrier Safety Administration**

# **Factors Associated with TBI and Crash Risk - Summary**

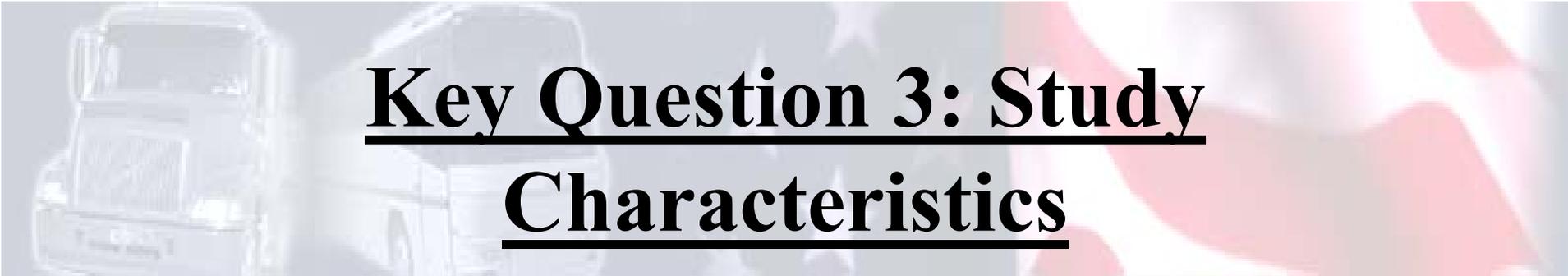
- The available evidence is insufficient to determine whether any factors related to TBI can predict actual crash risk. However, current evidence suggests that cognitive function measured by certain neuropsychological tests may predict the outcome of driving performance measured by a road test for patients with TBI. (Strength of Evidence: Moderate)**

**Federal Motor Carrier Safety Administration**

# Key Question 3: Impact of Post-TBI Rehabilitation on Crash Risk



- 1 low-quality cohort study included
- No specific enrollment of CMV drivers



## Key Question 3: Study Characteristics

- Study compared on-road driving performance of individuals with TBI who had full motorized-vehicle training (n = 13) to individuals with TBI who did not have full training (n = 11).
- Study enrollees had severe TBI.
- Study did not control for potential confounding factors (driving exposure, age, etc.).



**Federal Motor Carrier Safety Administration**

# Key Question 3: Impact of Post-TBI Rehabilitation on Crash Risk - Results

- The study found statistically significant differences between groups (favoring full vehicle training) on the post-training scores for percent tracking, percent correct signs, composite score, and the driver educator's score.



**Federal Motor Carrier Safety Administration**



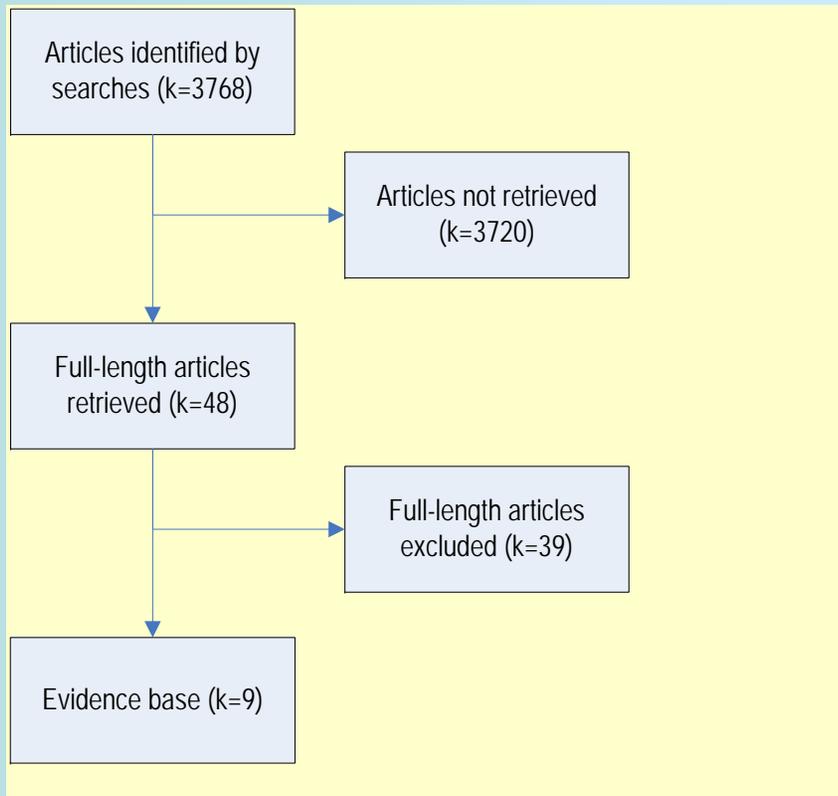
# **Impact of Post-TBI Rehabilitation on Crash Risk - Summary**

- **The available evidence is insufficient to determine the impact of rehabilitation programs on crash risk or driving performance among individuals with TBI.**



**Federal Motor Carrier Safety Administration**

# Key Question 4: Likelihood of Future Seizure among Individuals with TBI



- 9 studies included
- No CMV drivers
- All cohort studies
- Quality = 8 moderate, 1 low

# **Key Question 4: Likelihood of Future Seizure among Individuals with TBI**

- Late seizures defined as occurring  $>7$  days after TBI; also referred to as unprovoked seizures.
- Included studies had to report either percent of patients with a first-time late seizure (and no early seizures) or present the data in a manner that allowed independent calculation of percentages (number with first-time late seizures divided by total number with no early seizures).

# Key Question 4: Study Characteristics

Reference	Year	Severity of TBI	Method of classifying severity of TBI	Seizure reports assessed by neurologists blinded to patient identity/characteristics?
Diaz-Arrastia et al.	2003	Moderate or severe	CT scan findings	Yes
Englander et al.	2003	Moderate or severe	GCS score or CT scan findings	Yes
Annegers et al.	1998, 1980	Mild (60.7%), Moderate (32%), Severe (7.2%)	LOC or length of post-traumatic amnesia	NR
Murri et al.	1992	Severe	CT scan findings or LOC	NR
Heikkinen et al.	1990	Mild, moderate or severe	GCS score	NR
McQueen et al.	1983	Severe	Imaging findings or length of post-traumatic amnesia	NR
Wohns and Wyler	1979	Severe	NR	NR
Jennett	1975	Mild, moderate or severe	Length of post-traumatic amnesia and imaging findings	NR
Weiss and Caveness, Evans	1972, 1963	NR; all war injuries, 56% missile, 44% nonmissile	NR	NR
NR: Not reported				

# **Key Question 4: Likelihood of Future Seizure among Individuals with TBI**

- Generalizability to CMV drivers may be less important because question does not address crash/driving performance.
- Generalizability relative to age and gender might be important, if these factors influence seizure risk.
- Women are overrepresented relative to the CMV driver population, but most studies generalizable by age
- CMV drivers are on the road much longer than other drivers; increases chance of seizure while driving.

**Federal Motor Carrier Safety Administration**

# **Key Question 4: Likelihood of Future Seizure among Individuals with TBI**

- Differences among studies in potential confounding factors (severity of TBI, how severity was determined, length of follow-up, whether children were analyzed with adults, whether patients with alcoholism were included, whether anti-seizure medicine was used prophylactically)
- Therefore, study results not combined in a meta-analysis



**Federal Motor Carrier Safety Administration**

# Key Question 4: Results

Reference	Year	Number with TBI (number without early seizure)	Severity of TBI	Length of follow-up	Likelihood of late seizure among patients who did not have an early seizure
Diaz-Arrastia et al.	2003	106 (99)	Moderate or severe	6 months	17/99 = 17.2%
Englander et al.	2003	647 (626)	Moderate or severe	24 months or until a first confirmed seizure event >7 days after TBI	61/626 Cumulative probability (Kaplan-Meier) = 13.1%
Annegers et al.	1998, 1980	4541 (4424) (includes children [38%] and adults [62%])	Mild (60.7%), Moderate (32%), Severe (7.2%)	A minimum of 11 years or until first unprovoked seizure or death	Adults + children: 85/4424 = 1.9% Adults only: Mild TBI: 8/1024 = 0.8% Moderate TBI: 5/441 = 1.1% Severe TBI: 13/122 = 10.7% Total: 26/1587 = 1.6%*
Murri et al.	1992	293 (287) (includes children [30%] and adults [70%])	Severe	12 months	3/287 = 1.0% (all patients had prophylaxis with Phenobarbital)
Heikkinen et al.	1990	55 (45)	Mild, moderate or severe	Mean: 5.7 years (range 4.5-6.8 years)	5/45 = 11.1%
McQueen et al.	1983	164 (includes 43 children)	Severe	24 months	15/155 = 9.7%
Wohns and Wyler	1979	62 (only 50 with useful data)	Severe	Up to 24 months	5/50 = 10% (all treated with phenytoin)
Jennett	1975	1106 total (868) 783 adults (663)	Mild, moderate or severe	NR	<u>Adults</u> <u>Adults + Children</u> 22/663 = 3.3%                      29/868 = 3.3%
Weiss and Caviness, Evans	1972, 1963	356 (330)	NR; all war injuries, 56% missile, 44% nonmissile	8-11 years	83/330 = 25.2% Missile TBI: 66/208 = 31.7%* Nonmissile TBI: 7/135 = 5.2%*

NR: Not reported

# **Key Question 4: Likelihood of Future Seizure among Individuals with TBI**

- First-time late seizure rates ranged from 1% to 25% across studies.
- Highest rate (25%) associated primarily with missile TBIs.
- One study of patients with closed TBIs found that first-time, late seizures occurred more frequently among patients with severe TBI compared to those with moderate or mild TBI.

# Key Question 4: Results

Reference	Year	Total patients with first-time late seizures	Time of onset of first late seizure and number or percent of patients with first seizure in each time period										
			≤1 year	1-5 years	>5 years								
Annegers et al.	1980	<b>Adults only:</b> Mild TBI: 0.8% Moderate TBI: 1.1% Severe TBI: 10.7%	≤1 year	1-5 years					>5 years				
			0.1%	0.7%*					NR				
			1.0%	0.6%*					NR				
Weiss and Caviness	1972	83	≤1 year	1-2 years	2-3 years	3-4 years	4-5 years	5-6 years	6-7 years	7-8 years	8-9 years	9-10 years	10-11 years
			45	15	6	3	1	4	1	6	1	0	1
													7.7%
		<b>All patients:</b> Mild TBI: 0.7% Moderate TBI: 1.6% Severe TBI: 9.8%	0.1%	0.5%*					NR				
			0.7%	0.9%*									
			7.1%	4.5%*									

\*Expected percentages if all patients had been followed for 5 years

NR: Not reported



# **Likelihood of Future Seizure among Individuals with TBI - Summary**

- **Individuals with TBI who have not experienced a seizure within the first week post-injury still have a significant likelihood of experiencing late seizure(s). Reported frequencies of late seizures in this population ranged from 1% to 25% during follow-up periods ranging from 1 to 11 years. (Strength of Evidence: Moderate)**

# **Likelihood of Future Seizure among Individuals with TBI - Summary**

- **The highest rate of late seizures (25%) was associated primarily with penetrating missile TBIs. (Strength of Evidence: Minimally Acceptable)**
- **Among patients with closed TBIs, a diagnosis of severe TBI was associated with higher frequencies of first-time late seizures than diagnoses of mild or moderate TBI. (Strength of Evidence: Minimally Acceptable)**

# **Likelihood of Future Seizure among Individuals with TBI - Summary**

- **Among adults with moderate or severe TBI who develop late seizures,  $\geq 50\%$  experience their first late seizure within the first year after TBI. The rates fall substantially within the next two years and stabilize after the third year at roughly 2-4% (of the total patients who develop late seizures) per year out to 11 years. The pattern for mild TBI is less clear, but the rate of late seizure development does not appear much higher in the first year compared to subsequent years. (Strength of Evidence: Minimally Acceptable)**

**Federal Motor Carrier Safety Administration**