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*M. A. K. Ryan
D. W. Lloyd
A. M. S. Conlin
G. R. Gumbs
H. T. Keenan*



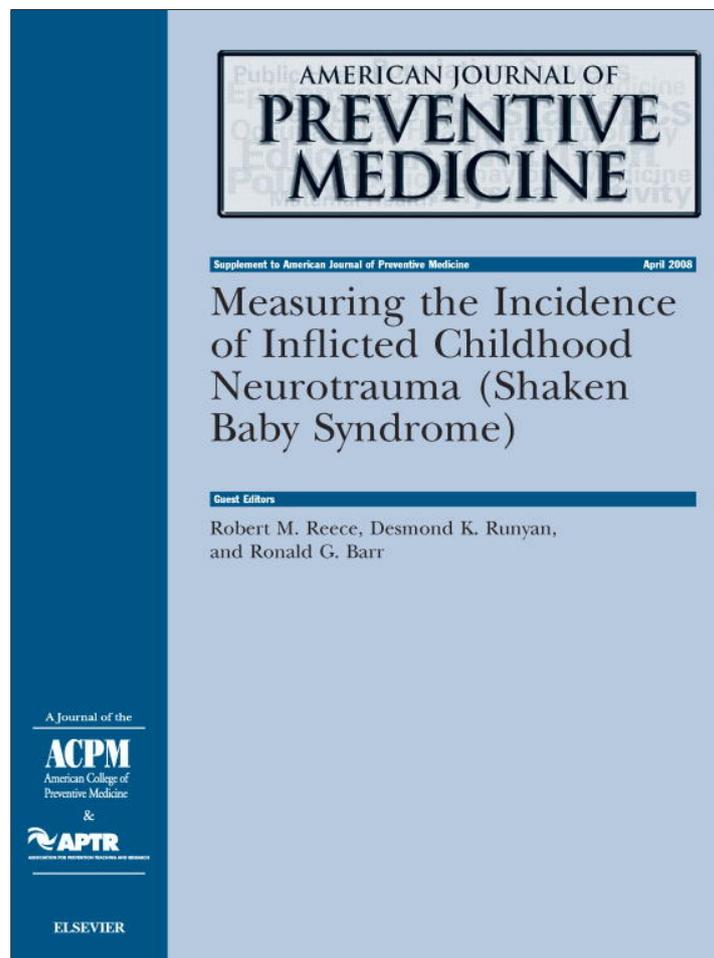
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Evaluating the Epidemiology of Inflicted Traumatic Brain Injury in Infants of U.S. Military Families

Margaret A. K. Ryan, MD, MPH, David W. Lloyd, JD, Ava M. S. Conlin, DO, MPH, Gia R. Gumbs, MPH, Heather T. Keenan, MDCM, PhD

Background: Evaluating the incidence of inflicted traumatic brain injuries (inflicted TBI) in young children, and encompassing shaken baby syndrome (SBS) and related injuries, is an epidemiologic challenge. Data available regarding military families in the U.S. may complement other national surveillance efforts.

Methods: A protocol was developed to assess the epidemiology of inflicted TBI among infants of U.S. military families, integrating data from the Department of Defense Birth and Infant Health Registry, healthcare utilization databases, child abuse reporting systems, and military personnel databases. The in-progress protocol, and its inherent strengths and limitations, are described here.

Discussion: The primary strengths of data from U.S. military families are related to the full characterization of the denominator, such that analyses are person-time and population based. Unique data are available to describe the full population of military parents, including occupational, geographic, and socioeconomic factors, as well as deployment-related potential stressors. The limitations of military data are similar to many other child abuse surveillance systems in that cases are underreported and not fully characterized. Linking abuse reports and medical utilization data to population data, however, will allow unique analyses of “probable” and “possible” cases of inflicted TBI in infants of military families.

Conclusions: Data from the U.S. military, when appropriately linked and analyzed, provide opportunities to evaluate important risk factors for inflicted TBI in infants. Although epidemiologic challenges may make incidence rates using military data noncomparable to rates using other data sources, multivariate analyses can evaluate critical and unique risk factors, as well as the effectiveness of prevention initiatives.

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Background

Inflicted traumatic brain injury (inflicted TBI) in infants, which encompasses shaken baby syndrome (SBS) and other abuse-related head trauma, is the most common cause of mortality and long-term morbidity in physically abused children.¹ Guthkelch² in 1971 called attention to the relationship between infant subdural hematoma and whiplash injuries. Caffey³ in 1972 theorized that shaking was responsible for retinal hemorrhages and subdural or subarachnoid hemorrhages in some infants. In 1974, he named this the “whiplash shaken baby syndrome” and attributed perma-

nent brain damage to this practice.⁴ Others described the absence of evidence of external cranial trauma in cases.^{4–6} Like most presentations of child maltreatment, cases of inflicted TBI are underreported and, because the spectrum of outcomes from inflicted TBI can range from subtle to severe among affected children,^{7–14} evaluating the incidence of inflicted TBI is an epidemiologic challenge.

Since inflicted TBI has severe consequences on victims and families, as well as medical and educational systems, evaluating and preventing inflicted TBI are of great public health importance. This is true for society in general, but may have special relevance in military communities. Inherent components of military service, such as extended work hours, prolonged separations due to deployment, and frequent relocation, subject military families to unique stressors that could place them at increased risk for dysfunction. Recent prolonged deployments in support of the global war on terrorism have been associated with increased risk for child maltreatment.^{15,16} Additionally, as many as 30%–60% of military service members have histories of being

From the Department of Defense Center for Deployment Health Research (Ryan, Conlin, Gumbs), San Diego, California; Department of Defense Family Advocacy Program, Office of the Under Secretary of Defense for Personnel and Readiness/Military Community and Family Policy (Lloyd), Washington DC; Department of Pediatrics, University of Utah (Keenan), Salt Lake City, Utah

Address correspondence and reprint requests to: Margaret Ryan, MD, MPH, Director, Department of Defense Center for Deployment Health Research, Naval Health Research Center (NHRC), 140 Sylvester Road, San Diego CA 92106. E-mail: margaret.ryan@med.navy.mil.

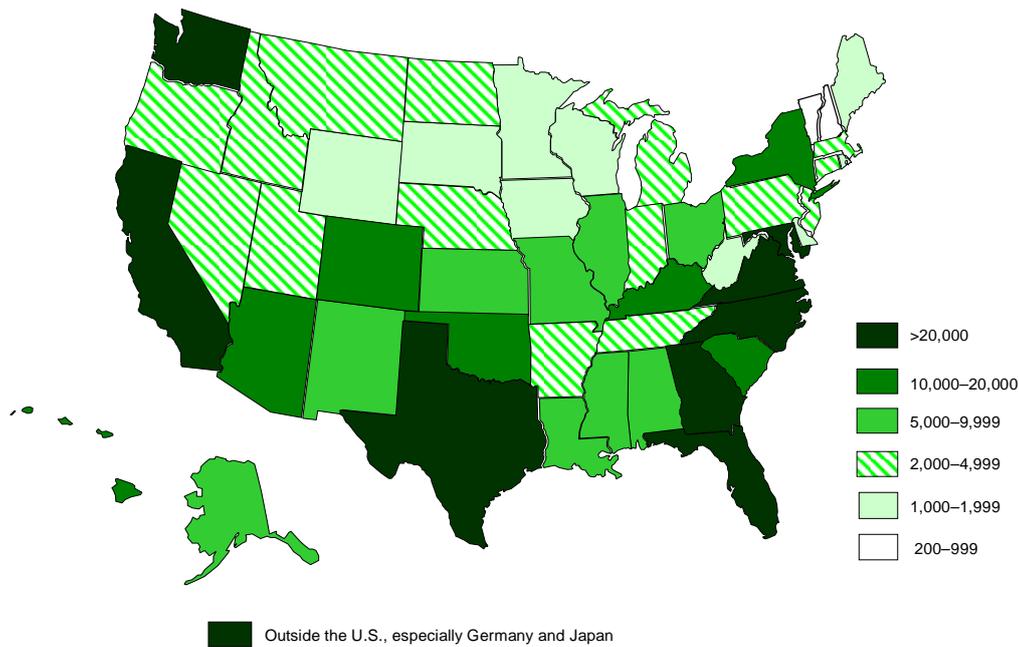


Figure 1. Geographic distribution of infants born to U.S. military families, 1998–2003.

victims of childhood maltreatment, and some studies have associated such victimization with an increased risk for perpetrating abuse in adulthood.^{17–20} Studies comparing child maltreatment between military and civilian families both support and refute the notion that children in military families are at increased risk for abuse,^{16,21–26} but all demonstrate that abuse is an important issue in the military.

Methods

The Department of Defense (DoD) Birth and Infant Health Registry was established in 1998 to evaluate the prevalence and incidence of important health outcomes among infants born to military families.²⁷ The system captures births of all infants financially sponsored by DoD, including infants born at all military and civilian medical facilities. These infants are then followed through the first year of life, capturing all inpatient and outpatient healthcare encounters, at both military and civilian facilities. The DoD Birth and Infant Health Registry thus provides an opportunity for population-based surveillance with well-defined infant-years of observation. Complete data exist for approximately 720,000 infants born to military families between 1998 and 2004.

Military family births occur in all 50 states and in 20 countries outside the U.S., with data captured in the same systems. **Figure 1** shows the geographic distribution of military family births. Most (76%) of the infants in military families are born to men on active duty who are married to civilian women (**Figure 2**). Fewer infants (7%) are born to dual-military parents; 6% are born to military women married to civilian men, and 6% are born to military women who are unmarried.

Important information on military parents can be obtained from personnel records of the Defense Manpower Data Center. Demographics include age, race/ethnicity, educa-

tional attainment, marital status, occupational specialty, service branch, and rank or pay-grade. Changes in dynamic variables are evaluated by reviewing monthly downloads of the current status of all military members. Relocation and deployments of military members are also well-defined by these personnel databases.

Healthcare data from the DoD Birth and Infant Health Registry routinely describe infant health metrics, including preterm births, multiple births, and the diagnosis of birth defects in the first year of life. To assess potential inflicted TBI, the healthcare encounter codes listed in **Table 1** also are evaluated. Diagnostic codes are derived from the ICD-9-CM.

The Department of Defense Birth and Infant Health Registry data will be linked to the database of the DoD Family

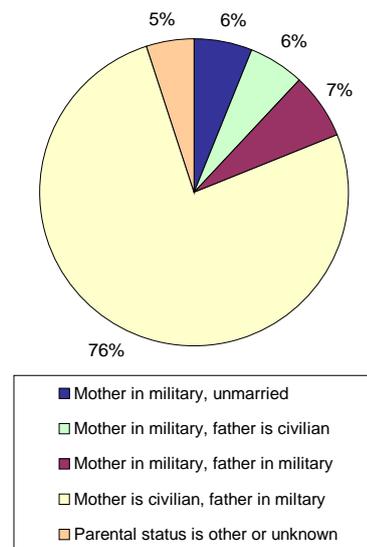


Figure 2. Parental characteristics of infants born to U.S. military families, 1998–2003.

Table 1. ICD-9-CM codes used to select potential cases of inflicted traumatic brain injury

Intracranial injury with skull fracture*	
800.xx	Fracture of vault of skull
801.xx	Fracture of base of skull
803.xx	Other and unqualified skull fracture
804.xx	Multiple fractures involving skull or face with other bones
Intracranial injury with no skull fracture*	
850.x	Concussion
851.xx	Cerebral laceration and contusion
852.xx	Subarachnoid, subdural, and extradural hemorrhage after injury
853.xx	Other and unspecified intracranial hemorrhage following injury
854.xx	Intracranial injury of other and unspecified nature
959.01	Head injury, unspecified
362.81	Retinal hemorrhage
Child abuse codes	
995.50	Child abuse, unspecified
995.54	Child physical abuse
995.55	Shaken infant syndrome
995.59	Other child abuse and neglect

*The fourth digit of codes 800.xx to 804.xx denotes the type of intracranial injury. The fourth digit of codes 851.xx to 854.xx denotes an open or closed wound. The fifth digit of the head-injury codes denotes level of consciousness or time period of unconsciousness.

Advocacy Program (FAP). These data show reported cases of child abuse and neglect, as well as whether such reports were substantiated by review of multidisciplinary teams. The FAP system defines the victim and the alleged perpetrator in maltreatment cases, and provides some information on severity. FAP data do not, however, include medical details that would distinguish inflicted TBI from other manifestations of maltreatment.

Given the above, “probable” cases of inflicted TBI may be considered as: ICD-9–coded head trauma plus ICD-9–coded abuse, or ICD-9–coded head trauma, plus temporally-related FAP-confirmed abuse, or ICD-9–coded retinal hemorrhage plus temporally-related FAP-confirmed abuse. Similarly, “possible” cases of inflicted TBI may be considered as: ICD-9–coded head trauma, retinal hemorrhage, or posterior rib fractures, plus nontemporally-related FAP-defined abuse or FAP-defined neglect. Sensitivity analyses can also be performed using the broadest definition of outcome, that is, all

ICD-9–coded head trauma or retinal hemorrhage, regardless of FAP-confirmation data.

Table 2 shows a sample size and statistical power analysis that may be applied to the protocol described here. The expected incidence of probable inflicted TBI is 30 per 100,000 infant-years,²⁴ but preliminary analyses of healthcare data suggest that rates of all TBI (regardless of mechanism) may be as high as 260 per 100,000 infant-years. Note that the latter gives the upper limit of the potential outcome measure, and it is a sensitive, but not specific, metric. One important exposure variable in these analyses is parental deployment within the year prior to infant birth; and this is expected to be evident for 20%–40% of military parents. Table 2 therefore demonstrates that, with a sample size of 720,000 infants, this protocol has ample power to detect statistically significant ORs as small as 1.5, even for the relatively rare outcome of probable inflicted TBI.

Discussion

Evaluation of data used in the protocol described here reveals important limitations that must be considered when assessing rates of inflicted TBI in infants of military families. The population that is well described by the DoD Birth and Infant Health Registry is restricted to infants born to the families of active-duty service members. That is, infants born to members before they begin service, and infants born to Reserve/Guard members are not included in the surveillance population because all of their healthcare utilization in infancy is not visible in DoD data. It is equally important to consider that healthcare encounters are required to be captured as inflicted TBI cases; fatal cases that never present to a medical provider may be missed.

Like all surveillance systems for child abuse, this protocol may fail to include inflicted TBI cases that are considered to be accidental by providers and/or not reported through FAP mechanisms. This limitation may be mitigated partially, but not completely, through the supplementary sensitivity analyses, applying broader definitions for potential cases of inflicted TBI.

It is also important to note that the FAP system was not designed for epidemiologic research; it was designed to identify and respond to abuse and neglect in

Table 2. Sample size and statistical power analyses for evaluating data on inflicted traumatic brain injury among infants in U.S. military families

Expected frequency of outcome	Statistical power (%)	Frequency of exposure of interest (e.g., parental military deployment) (%)	N required for significant OR		
			OR=1.2	OR=1.5	OR=2.0
30/100,000	80	20	4,573,443	853,871	268,450
		40	3,214,936	643,607	222,681
	90	20	6,186,831	1,170,014	373,877
		40	4,318,805	868,215	301,945
260/100,000	80	20	529,390	98,873	31,094
		40	372,042	74,479	25,763
	90	20	716,107	135,462	43,295
		40	499,776	100,466	34,931

military families. Its focus, therefore, is on military sponsors, around whom most actions for intervention and prevention revolve. This means that abuse and neglect cases in military families in which the perpetrator is someone other than the military parent may be less likely to be reported to the FAP system. Although this limits generalizations about overall inflicted TBI rates, it does allow stratified analyses to focus on, for example, families with the father as military sponsor, where data are relatively complete and stronger analyses of modifiable risk factors can be pursued.

Strengths of this protocol are related primarily to full characterization of the denominator of individuals at risk. That is, analyses will be population-based and nearly fully capture data on all infant-years. This is a great advantage over numerator-based systems.²⁷ From the 7 years of available data, approximately 720,000 infant-years are included in analyses, and this provides enough statistical power to assess the relatively rare outcome of inflicted TBI.

It is also important to note that a wide geographic area is covered by the military population, with consistent mechanisms for data capture. Military data, therefore, may provide an opportunity to evaluate potential geographic differences in rates that are not prone to the usual problems of capturing data across disparate state surveillance systems.

The most important feature of military family data is the full visibility on parents who are active-duty members. Stratified subsets can be defined, and multivariate analyses applied, so that risks related to the education, occupation, and socioeconomic status of perpetrators can be extremely well-quantified. One of the most critical potential risks that this protocol will address, of course, is the relationship between deployment to war zones in recent years and the inflicted TBI on infants in military families.

Less obvious, but equally important, strengths of these analyses are related to some homogeneity within the population at risk. Military families have virtually equal access to the same medical system, regardless of other socioeconomic factors, and this may allow the consistent capture of critical healthcare utilization data.²⁸ Similarly, the FAP is applied consistently across the large population, regardless of member-specific or geographic factors.

Finally, it should be noted that the use of outpatient care data is a relatively unique attribute of the described protocol that allows the capture of potentially less-severe inflicted TBI cases and/or inflicted TBI cases that present for care after some time has passed from the acute event. While potentially providing a fuller picture of the inflicted TBI spectrum, this feature, in combination with many of the aforementioned features, make incidence rates calculated here not directly comparable to incidence rates calculated from other systems.

Conclusion

The protocol described here provides an opportunity to make unique insights about risk factors for inflicted TBI in infants. Specifically, the relationship between this form of child abuse and military deployment, multiple deployments, and/or relocations, can be fully explored. Because these are potentially modifiable risk factors or opportunities for intervention, these analyses have special value. It also should be noted that these potential risk factors are not unique to military families, since other parental occupations may be associated with similar challenges.

Likewise, occupational factors in military parents, beyond deployment and relocation, can be fully explored in this protocol. Differences in risk between construction workers and combat specialists, for example, may provide unique insight into other parental stressors. And, with consistent access to health care and the FAP system, socioeconomic factors as risks for family dysfunction can be isolated and quantified, providing insight into these factors that may have applicability to the general population.

Finally, perhaps the greatest value in evaluating a consistent data system, over several years and across a large population, is the opportunity to assess the effectiveness of prevention and intervention initiatives. Several prevention initiatives have been applied to small segments of the military population over the past several years. Assessment of such initiatives is usually limited to the evaluation of surrogates for success, such as increased parental knowledge about inflicted TBI. In evaluating military data on inflicted TBI incidence, as described here, important insights may be achieved on the actual value of prevention and/or intervention efforts, with the goal of reducing the tragic consequences of inflicted TBI in all populations.

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14. ABSTRACT (maximum 200 words)

Background: Evaluating the incidence of inflicted traumatic brain injuries in young children, encompassing “shaken baby syndrome” and related injuries, is an epidemiologic challenge. Data available on US military families may complement other national surveillance efforts.

Methods: A protocol was developed to assess the epidemiology of inflicted traumatic brain injuries among infants of US military families, leveraging data from the Department of Defense Birth and Infant Health Registry, healthcare utilization databases, child abuse reporting systems, and military personnel databases. The protocol and data strengths and limitations are described.

Results: The primary strengths of data from US military families are related to full characterization of the denominator, such that analyses are person-time and population-based. Unique data are available to describe the full population of active-duty military parents, including occupational, geographic, and socioeconomic factors, as well as deployment-related potential stressors. The limitations of military data are similar to many other child abuse surveillance systems in that cases are underreported and not fully characterized. Linking abuse reports and medical utilization data to population data, however, will allow unique analyses of “probable” and “possible” cases of inflicted traumatic brain injuries in infants of military families.

Conclusions: US military data, when appropriately linked and analyzed, provide opportunities to evaluate important risk factors for inflicted traumatic brain injuries in infants. Although epidemiologic challenges may make incidence rates using military data not comparable to rates using other data sources, multivariable analyses can evaluate critical and unique risk factors, as well as the effectiveness of prevention initiatives.

15. SUBJECT TERMS
military, infant health, shaken baby syndrome

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