

**Costs of Military Eye Injury, Vision Impairment, and Related Blindness
and Vision Dysfunction Associated with Traumatic Brain Injury (TBI) without Eye Injury**

**Prepared by:
Kevin D. Frick, PhD
Professor, Johns Hopkins Bloomberg School of Public Health**

**Submitted on:
May 6, 2012**

Kevin Frick (kfrick@jhsph.edu) performed the work for this paper under a consulting contract with the National Alliance for Eye and Vision Research (NAEVR). In Dr. Frick's professional opinion, this work represents the aggregation of the best available evidence on the incidence and cost of vision dysfunction and blindness in the US military from 2000-2010. This work does not represent the viewpoint of the Johns Hopkins Bloomberg School of Public Health.

For more information contact:
National Alliance for Eye and Vision Research (NAEVR)
1801 Rockville Pike, Suite 400
Rockville, Maryland 20852
James Jorkasky, Executive Director
240-221-2905, jamesj@eyersearch.org

TAKE AWAY MESSAGE

Based on published data from 2000-2010, the total incident cost of eye injury in the military each year in this timeframe has been \$2.282 billion, which represents superficial eye injury, non-superficial eye injury that does and does not result in permanent visual impairment or blindness, and vision impairment related to Traumatic Brain Injury (TBI). If we multiply the one-year costs by 11 to account for the period from 2000-2010, the total cost to the economy of all ocular injury and vision impairment related to TBI is \$25.107 billion. Of that total, the costs incurred in the first year (all for superficial injury, initial medical care for non-superficial injuries, and rehabilitation for bilateral vision impairment) are \$634 million. This is money that has already been spent. The present value of the projected Department of Veterans Affairs (VA) benefits for the remainder of the lives of all service members with ocular injuries in the 11 years under study is \$188 million. The present value of the projected costs to the remainder of the economy over the remaining lifetimes of the service members with eye injuries or vision impairment due to TBI is \$24.286 billion. This last cost is not to the federal government but to the economy and society as a whole.

I. INTRODUCTION

This report will focus on several groups of service members that have eye injuries and/or vision impairments related to their service. Figure 1 shows how these groups are divided and the different types of costs they incur. Each of the three large sections (one is divided into subsections) is a different color as a reminder of the three separate groups. Each box contains a bold text label of which group is represented and then a plain text list of costs that are experienced.

The entire group with ocular injury is represented by the combination of group A (the white box) and groups B1-B3 (the three small light gray boxes). Group A has superficial eye injury. The incidence of eye injury in general and superficial eye injury in particular will be described in Section IIA. As shown in the box, the group with superficial eye injury (defined below) experiences only the cost of initial treatment, workers' compensation indemnity payments, and the value of the loss of missed workplace activity that is not paid for by indemnity payments. The assumption that there is no permanent visual impairment from superficial injuries may be incorrect, but there is currently no data readily available to indicate the proportion that should be assumed to have vision impairment after superficial ocular injury.

The group with non-superficial eye injury is represented by the three light gray boxes and the incidence of these events will also be described in Section IIA. The group with non-superficial eye injury is further divided into three groups. Group B1 consists of those who have a non-superficial injury without permanent visual impairment and the costs incurred are listed in the B1 box. Group B2 consists of those who have a non-superficial eye injury that results in permanent visual impairment but not bilateral blindness, and their costs are listed in the B2 box. Their incidence is discussed in the section on costs (Section IIIB2). Group B3 consists of those who have a non-superficial eye injury that results in permanent bilateral blindness and their costs are listed in the B3 box. Their incidence is discussed in the cost section (Section IIIB3).

The final group, Group C, shown in the bottom dark box in Figure 1, are those with a traumatic brain injury without an ocular injury but report permanent visual impairment. The components

of their costs are listed. Their incidence is discussed in Section IIB and their costs are discussed in Section IIIC.

Figure 1. Groups of Service Members Described in this Report

<p>A. Superficial Eye Injury</p> <ol style="list-style-type: none"> 1. Initial Treatment 2. Workers’ Compensation Indemnity Payment 3. Value of Missed Work 	<p>B1. Non-Superficial Eye Injury with no Permanent Vision Impairment</p> <ol style="list-style-type: none"> 1. Cost of Initial Treatment
	<p>B2. Non-Superficial Eye Injury, Permanent Vision Impairment—not Bilateral Blindness</p> <ol style="list-style-type: none"> 1. Cost of Initial Treatment 2. Excess unemployment 3. Decreased pay even if employed 4. Excess medical care 5. Excess family support
	<p>B3. Non-Superficial Eye Injury, Permanent Bilateral Blindness</p> <ol style="list-style-type: none"> 1. Cost of Initial Treatment 2. Excess unemployment 3. Excess medical care 4. Excess family support 5. VA Benefits
<p>C. Vision Impairment Related to TBI Without Ocular Injury</p> <ol style="list-style-type: none"> 1. Excess unemployment 2. Decreased pay even if employed 3. Excess medical care 4. Excess family support 	

II. INCIDENCE

IIA.

How Many Members of the Military Are Affected by Ocular Injuries?

Hilber (2011) reported the number of incident eye injuries among the active component of the United States military between the years 2000 and 2010. The total number of incident injuries was 182,525 ambulatory and another 4,030 hospitalized. These were divided into superficial and non-superficial. The number of superficial injuries (defined as “abrasions and external foreign bodies”) was 133,274 ambulatory and 532 hospitalized. The number of non-superficial injuries was then divided into high risk of blindness (defined as “perforating/penetrating trauma, globe rupture, intraocular foreign body”) and other. There were further classifications but they are not of interest to an analysis of cost in which there is little differentiation of the injuries for which cost data can be easily obtained. The number of high risk of blindness injuries was 4,852

including both ambulatory and hospitalized. Throughout the analyses, we divide the totals by 11 to obtain an annual figure. Please see Table 1 for the annualized figures. These annual figures are obviously an average over the course of conflict since the year 2000. The number of injuries in future years may be higher (if higher levels of conflict resume) or lower (if we are unlikely to see as high levels of conflict again in the future). The inability to predict an exact number of injuries per year in the future is a limitation, but this report provides a useful average over the course of time since the conflicts in Afghanistan and Iraq began.

Table 1. Annualized Number of Injuries

<u>Type of Injury</u>	<u>Annualized Number</u>
Superficial	12,164
Non-Superficial	4,795
High Risk of Blindness (subset of non-superficial)	441
Total	16,960

Calculated based on Hilber (2011)

IIB.

How Many Other Members of the Military Have Vision Impairment Associated with Traumatic Brain Injury (TBI) but Do Not Have a Reported Ocular Injury?

We assume that individuals who had eye injury and traumatic brain injury would already be captured by the eye injury data above. This section focuses on estimating the number who have traumatic brain injury that is the cause of vision impairment.

The Defense and Veterans Brain Injury Center (BVBIC) reported the incidence of traumatic brain injury from the start of 2000 through the fourth quarter of 2011 as 233,425 (<http://www.dvbic.org/pdf/dod-tbi-2000-2011Q4-as-of-120210.pdf> accessed on 5/2/12).

Although the TBI's are mild, moderate, severe, penetrating, and not classifiable, we focus on the total. Cockerham et al. (2009) reported on vision impairment among military service individuals who had TBI. They reported that 75% of those presenting with TBI had self-reported visual dysfunction or impairment. The incidence rate is thought to be similar across all levels of TBI (personal communication with Dr. Gregory Goodrich who is a coauthor on the Cockerham et al. paper cited in Section IIB). Thus, 175,096 service men and women had a complaint but no injury. However, other sources of data report the prevalence of blindness and permanent visual impairment that is not legal blindness being 2.76% (Congdon et al., 2004) and the percentages who self-report as having some problem seeing faces, reading newspapers, both, or legal blindness in a large national survey (Medical Expenditure Panel Survey) being 8.9%. If we assume that the self-report is 100% sensitive, we calculate a positive predictive value (i.e., the number who self-report visual impairment who are actually visually impaired) equal to approximately 31.0% (calculated). Thus, we calculate that 54,291 individuals had some level of vision dysfunction over the 11 years. Dividing by 11 (the incidence data include 2000 through the fourth quarter of 2011) we find 4,935 cases per year of service members who suffered a traumatic brain injury associated with some degree of vision impairment afterwards without ocular injury. See Table 2 for details of these calculations.

Table 2. Incidence of Cases of Traumatic Brain Injury (TBI) Contributing to Vision Impairment

<u>Category</u>	<u>Number</u>	<u>Prevalence (%)</u>
Cases of TBI (2000-Q1 2010)	233,425 (DVBIC)	
Subjective Visual Impairment Positive Predictive Value	175,069 (calc.)	75.0 (Cockerham et al.) 31.0 (Congdon et al. & MEPS)
Estimated Visual Impairment	54,291 (calc.)	
Annualized Visual Impairment	4,524 (calc.)	

III. COSTS

IIIA. Superficial Eye Injury

IIIA1.

The Cost of Treating Service Members Experiencing Superficial Ocular Injury

Islam et al. (2000) reported on the cost of treating a variety of eye injuries. The cost was reported as \$196.50 in 1998 US dollars. This figure was adjusted for inflation to be appropriate for the start of the year 2012. Inflation adjustment data came from the Bureau of Labor Statistics series on medical care services for all urban consumers. The inflation-adjusted cost of treating each injury is calculated as \$344. The total cost of treating 12,164 annualized superficial eye injuries is estimated to be \$4.19 million. See Table 3 for the calculations.

Table 3. Cost of Treating Superficial Eye Injury

<u>Category</u>	<u>Amount</u>
Superficial Eye Injuries	12,164 (refer to Table 1)
Reported Cost Per Superficial Eye Injury	\$196.50 (in 1998 US dollars)
Inflation Adjusted Cost per Superficial Eye Injury	\$344.42 (using BLS data)
Annual Cost to Treat Superficial Eye Injuries	\$4,189,573 (calculated as 12,164 x 344.42)

IIIA2.

The Cost of Workers' Compensation Indemnity for Service Members Experiencing Superficial Ocular Injury

Islam et al. (2000) also reported on the proportion of injuries resulting in a workers' compensation indemnity payment. The proportion was 5.14%. The average number of days of payment was 8.5 (also from Islam et al., 2000). A source on VA compensation for service-connected disability indicated an annual salary of \$46,647 in 2006 for those with service-connected disabilities (Chapter 8, Final Report for the Veterans' Disability Benefits Commission: Compensation, Survey Results and Selected Topics). The cost for 8.5 days of indemnity payment (based on a 250 day work year) for the service members with superficial eye injuries is calculated at \$753,000 —assuming an indemnity of 66.7% of the value of the inflation-adjusted wage. See Table 4 for calculations.

Table 4. Workers Compensation for Superficial Eye Injury

<u>Category</u>	<u>Amount</u>
Annual Number of Superficial Eye Injuries	12,164 (above)
Annual Proportion with Workers' Compensation Claims	5.14% (Islam et al., 2000)
Annual Number with Workers' Compensation Claims	626
Average Number of Days of Claims per Person	8.5 (Islam et al., 2000)
Inflation Adjusted Average Salary for an Individual in 2012 US Dollars	\$53,078 (Chapter 8 & BLS)
Average Workers' Compensation Payment Per Person (based on 250 working days and 66.7% of salary paid)	\$1,204 (calculated)
Annual Total Workers' Compensation Payments in 2012 US Dollars	\$752,943 (calculated as 626 x 1,204)

IIIA3.

The Cost of Missed Work for Service Members Experiencing Superficial Ocular Injury

Islam et al. (2000) also pointed out that 70.16% of individuals with eye injury missed work. The average number of days missed was 2.8. Applying the same dollar value per day but not adjusting by two-thirds, the value of missed work time is calculated to be \$5.1 million. Please see Table 5 for calculations.

Table 5. Value of Missed Work for Superficial Eye Injury

<u>Category</u>	<u>Amount</u>
Annual Number of Superficial Eye Injuries	12,164 (above)
Annual Proportion with Workers' Compensation Claims	70.16% (Islam et al., 2000)
Annual Number with Workers' Compensation Claims	8,534
Average Number of Days of Work Missed per Person	2.58 (Islam et al., 2000)
Inflation Adjusted Average Salary for an Individual in 2012 US Dollars	\$53,078 (Chapter 8 & BLS)
Average Value of Work Time Lost Per Person (based on 250 working days)	\$594 (calculated)
Annual Total Value of Work Time Lost in 2012 US Dollars	\$5,073,188 (calculated as 8,534 x 594)

Summary of IIIA of Costs for Service Members' Superficial Ocular Injuries

The sum of costs for superficial eye injuries is \$10.0 million. Table 6 shows how this is summarized.

Table 6. Total Annual Cost of Superficial Eye Injury

<u>Item</u>	<u>Number</u>	<u>Amount (2012US\$)</u>
Medical Care (Table 3)	12,164	4,189,573
Workers' Compensation Indemnity Payment (Table 4)	626	752,943
Work Time Lost (Table 5)	8,534	5,073,188
Total		\$10,015,704

IIIB. Non-Superficial Eye Injury Costs of Immediate Treatment***IIIB1.******The Cost of Treating Service Members' Non-Superficial Ocular Injuries***

The cost of treating each non-superficial injury was estimated from data presented by Buckingham et al. (2005). This applies to all of the cases of non-superficial eye injury. This is the only cost that applies to those with non-superficial eye injury that does not result in permanent visual impairment or bilateral blindness. The costs were reported by service branch. We computed a weighted average cost per injured service member of \$5,555. The data are reported as money spent from 1988-1998 but it is not clear whether any inflation adjustment was made. Assuming that the figures were reported as 1998 dollars and inflation-adjusted using data from the Bureau of Labor Statistics similar to those used to adjust the cost of treating superficial injury, the inflation-adjusted cost would be \$9,736. Given the number of non-superficial injuries, the annual cost of treating these injuries is \$46.7 million. See Table 7 for the calculations.

Table 7. Cost of Initial Medical Care to Treat Non-Superficial Eye Injuries

<u>Category</u>	<u>Amount</u>
Number of Non-Superficial Eye Injuries	4,795 (Table 1)
Inflation-Adjusted Cost of Treating Each Non-Superficial Eye Injury (in 2012 US dollars)	\$9,736 (Buckingham et al. & BLS)
Total Cost of Treating Non-Superficial Eye Injuries	\$46,688,075 (calculated)

IIIB2. Non-Superficial Eye Injury Lifetime Costs for Visually Impaired Service Members***IIIB2a.******Costs for Visual Impairment That Does not Result in Bilateral Blindness and is Associated with Ocular Injury***

The first step in calculating the cost of vision impairment is calculating the number with vision impairment. The American Academy of Ophthalmology reports on eye injuries (<http://www.aaopt.org/newsroom/guide/upload/Eye-Injuries-BkgnderLongVersFinal-I.pdf>) that 16.9% of all eye injuries result in moderate impairment and 7.0% result in blindness. Taking 16.9% of the 93.0% not-blind and multiplying that by the number of non-superficial injuries less the number of blind cases already calculated, we obtain a number that is projected for vision impairment of 868 per year. See Table 8 for details of this calculation that shows that the incidence of vision impairment among non-blinding injuries that are non-superficial.

Table 8. Number of Incident Visually Impaired Individuals

<u>Category</u>	<u>Amount</u>
Annual Non-Superficial Eye Injuries	4,795
Annual Number Blind	21
Annual Percentage of Non-Blinding Injuries that Lead to Vision Impairment	18.2% (16.9% of 93% based on http://www.aao.org/newsroom/guide/upload/Eye-Injuries-BkgnderLongVersFinal-1.pdf)
Annual Number of Cases of Vision Impairment	868 (calculated as 18.2% of 4795)

Houtenville (2003) also provides data on the decrease in employment for the visually impaired, which is 6.5%. Each of these individuals is assumed to have the same lifetime loss of income as those who were blind and the total for the 868 cases is \$67.3 million. (Defined below. The calculations are otherwise identical to those in Table 15 except for VA benefits.) In addition, even those who are working (82.3%) have lower income. Rein et al. (2006) reported on reduced earnings for the visually impaired but not blind and the ratio (70.3% or a loss of 29.7%) was applied to the annual earnings figure used earlier. The lost wages for this much larger group were \$253.0 million. An additional \$4.8 million in family support was calculated assuming that the family provides 29.7% as much support for each visually impaired individual as it would for blind individuals. Lifetime excess medical care was based on a \$1,037 difference per person annually reported by Frick et al. (2007) and inflation-adjusted and otherwise calculated similarly to the way it was done for blind individuals. The total is \$27.8 million.

IIIB2b.

Summary of Total Cost for Service Members Who Have Suffered an Ocular Injury and Experienced Permanent Visual Impairment that is not Bilateral Blindness

The sum of the costs of visual impairment in the preceding paragraph is \$353.1 million. This is detailed in Table 9.

Table 9. Total Costs Related to Vision Impairment After Eye Injury for Service Members with an Ocular Injury that Results in Vision Impairment but not Bilateral Blindness

<u>Item</u>	<u>Number</u>	<u>Amount (2012US\$)</u>
Excess Unemployment	56	67,345,686
Decreased Pay	714	253,022,893
Excess Medical Care	868	27,853,663
Family Support	868	4,855,811
Total		\$353,078,053

IIIB3. Non-Superficial Eye Injury Costs in the First Year for Bilaterally Blind Service Members

IIIB3a.

Cost of Rehabilitation for Service Members Bilaterally Blind as a Result of Ocular Injuries

The number of individuals bilaterally blinded was calculated using the following process. We began with data from Kuhn et al. (2006). They reported the proportion blind from four different

types of conditions. We took a simple average and calculated it to be 43%. We used data from Thach et al. (2008) to calculate the number who would be bilateral (11.2%) leading to 21 bilaterally blind per year (11.2% of 43% of the 441 each year at high risk of blindness). The VA Blindness Rehabilitation Center costs per year are \$38,627 in 2006 US dollars (Stroupe et al., 2008). The inflation adjusted rehabilitation cost is \$43,952 using the consumer price index as reported by the BLS as Stroupe et al. (2008) had. The annual cost of rehabilitation is \$933,000. See Table 10 for calculations.

Table 10. Calculation of Rehabilitation Cost for Bilaterally Blind

<u>Category</u>	<u>Amount</u>
Number of Service Members at High Risk of Blindness	441 (Table 1)
Proportion at High Risk of Blindness Who Become Blind	43% (Kuhn et al.)
Proportion of Blind who are Bilaterally Blind	11.2% (Thach et al.)
Number of Bilaterally Blind Service Members Per Year	21 (calculated)
Cost of Rehabilitation within the VA in 2012 US dollars	\$43,952 (Stroupe et al. 2008 & BLS data)
Total Annual Cost of Rehabilitation in 2012 US dollars	\$932,611 (calculated as \$43,952 x 21)

IIIB3b. Non-Superficial Eye Injury Lifetime Costs for Bilaterally Blind Service Members

IIIB3bi.

Cost of Unemployment for Service Members Bilaterally Blind as a Result of Ocular Injuries
Houtenville (2003) reported a 39.4 % lower employment rate for those blind compared with those with normal sight. Each of these 8 extra unemployed individuals per year (39.4% of 21 individuals bilaterally blind as reported in Table 10) were assigned the full value of their expected pay for the remainder of their expected working lives. Hilber et al. reported an average age of 29 years for service members with eye injuries. Assuming a standard retirement age of 65 years, this means 36 working years remain. Using a 3 percent discount rate as recommended by the United States Panel on Cost-Effectiveness in Health and Medicine, the present value of these 36 years is 22.5 years. Applying the 22.5 year figure to the inflation-adjusted average annual salary of \$53,078 (Chapter 8 and BLS data), the total value of the loss of economic productivity for these eight service members was calculated at \$10.0 million. Please see Table 11 for calculations.

Table 11. Lifetime Wages Lost for Bilaterally Blind Service Members

<u>Category</u>	<u>Amount</u>
Number of bilaterally blind service members	21 (Table 10)
Average wage for service members inflation adjusted to 2012 US dollars	\$53,078 (Chapter 8 & BLS data)
Excess unemployment for blind individuals	39.4% (Houtenville, 2003)
Average age of service members with eye injuries	29 (Hilber, 2011)
Average number of remaining work years assuming retirement age of 65	36 years
Average present value of remaining work years assuming a 3% discount rate	22.5 years (calculated using method and rate from Gold et al., 1996)
Total Wages Lost	\$9,984,167 (calculated as 21 x 39.4% x 53,078 x 22.5)

*IIIB3bii.**Cost of Excess Medical Care for Service Members Bilaterally Blind as a Result of Ocular Injuries*

Frick et al. (2007) estimated the excess cost of medical care used by blind individuals compared with normally sighted individuals to be \$2,157 per year in 2007 dollars. The life expectancy for a 30 year old (the closest age reported to the age of 29 for the average age of those with eye injuries) is 77.7 years (<http://www.worldlifeexpectancy.com/country-health-profile/united-states> accessed on March 16, 2012). Applying a 3% discount rate, applying inflation adjustment to the figures using the medical care services price index, and assuming that the difference in expenditures otherwise remains the same as a blind individual ages, the lifetime excess expenditures for all the blind individuals is \$1.4 million. See Table 12 for the calculations.

Table 12. Lifetime Excess Medical Care Costs for Bilaterally Blind Individuals

<u>Category</u>	<u>Amount</u>
Number of Bilaterally Blind Individuals	21 (Table 10)
Excess Medical Care Expenditures Per Year in 2012 US Dollars	\$2,527 (Frick et al., 2007 and BLS data)
Average Age of Eye Injury	29 years (Hilber, 2011)
Life Expectancy of a 30 Year Old (http://www.worldlifeexpectancy.com/country-health-profile/united-states)	77.7 years
Present Value of Remaining Years Using a 3% Discount Rate	26.4 years (Applying rate and method from Gold et al., 1996)
Total Value of Lifetime Excess Medical Care in 2012 US Dollars	\$1,417,010

IIIB3biii.

Cost of Family Support for Service Members Bilaterally Blind as a Result of Ocular Injuries
Keeffe et al. (2009) reported the annual cost of extra family support to be \$710 which, after inflation adjustment, is \$759. Assuming that this is required for the remaining lifetime for all the blind individuals and discounting at 3%, this adds \$426,000 to the total burden. See Table 13 for details.

Table 13. Lifetime Value of Family Support for Annual Incident Cases of Bilateral Blindness

<u>Category</u>	<u>Amount</u>
Number of Bilaterally Blind Individuals	21 (Table 10)
Annual Cost of Family Support Per Person Inflated to 2012 US Dollars	\$759 (Keeffe et al., 2009, and BLS data)
Present Value of Remaining Years	26.4 years (see Table 12)
Total Cost of Lifetime Family Support	\$425,647 (calculated as 21 x 750 x 26.4)

IIIB3biv.

VA Benefits for Service Members Bilaterally Blind as a Result of Ocular Injuries
Blind veterans are eligible for a one time housing payment of up to \$63,780 (http://www.va.gov/opa/publications/benefits_book/benefits_chap02.asp), an automobile allowance (for someone to drive them) of \$18,900 (http://www.va.gov/opa/publications/benefits_book/benefits_chap02.asp), and a monthly allowance of \$2,673 (http://www.va.gov/opa/publications/benefits_book/benefits_chap02.asp). Projecting the last of these three over the remaining work years (assuming that other benefits become relevant at normal retirement age) the total accumulated benefit cost would be \$17.1 million. See Table 14 for details.

Table 14. VA Benefits for Bilaterally Blind Individuals

<u>Category</u>	<u>Amount</u>
Number of Bilaterally Blind Individuals	21 (Table 10)
Present Value of Remaining Work Years	22.5 years (Table 11)
Monthly Allowance Per Person	\$2,673
Lifetime Value of Monthly Allowance Per Bilaterally Blind Service Member	\$721,710
Housing Allowance Per Bilaterally Blind Service Member	\$63,780
Automobile Allowance Per Bilaterally Blind Service Member	\$18,900
Total Present Value of VA Benefits for Bilaterally Blind Service Members	\$17,068,101

IIIB3bv.

Summary of Total Cost for Service Members Bilaterally Blinded by Ocular Injury

The total lifetime costs that are incident annually for bilaterally blinded individuals is \$29.8 million. See Table 15 for a summary.

Table 15. Total Annual Cost Related to Incident Bilaterally Blinded Service Members

<u>Item</u>	<u>Number</u>	<u>Amount (2012US\$)</u>
Rehabilitation	21	932,611
Excess Unemployment	8	9,984,167
Excess Medical Care	21	1,417,010
Family Support	21	425,647
VA Benefits	21	17,068,101
Total		\$29,827,562

IIIC. Lifetime Costs for Service Members with Vision Impairment Associated with Traumatic Brain Injury but Without Ocular Injury

IIIC1. Summary of Lifetime Cost of Visual Impairment Associated with TBI without Ocular Injury

The lifetime per-service member costs of visual impairment that is not bilateral blindness sum to \$407,000 (average per visually impaired service member in Table 9). It is reasonable to assume that the costs related to vision impairment are the same when it results from TBI without ocular injury. Multiplying the cost per-service member figure by the number of cases of visual impairment related to TBI without ocular injury (4,524 as shown in Table 2) we calculate a total burden of \$1.843 billion.

IV. SUMMARY

Total Cost of Ocular Injury and Vision Impairment Related to TBI without Ocular Injury

The total incident cost of eye injury and vision impairment related to TBI in the military each year is \$2.282 billion. This is detailed in Table 16.

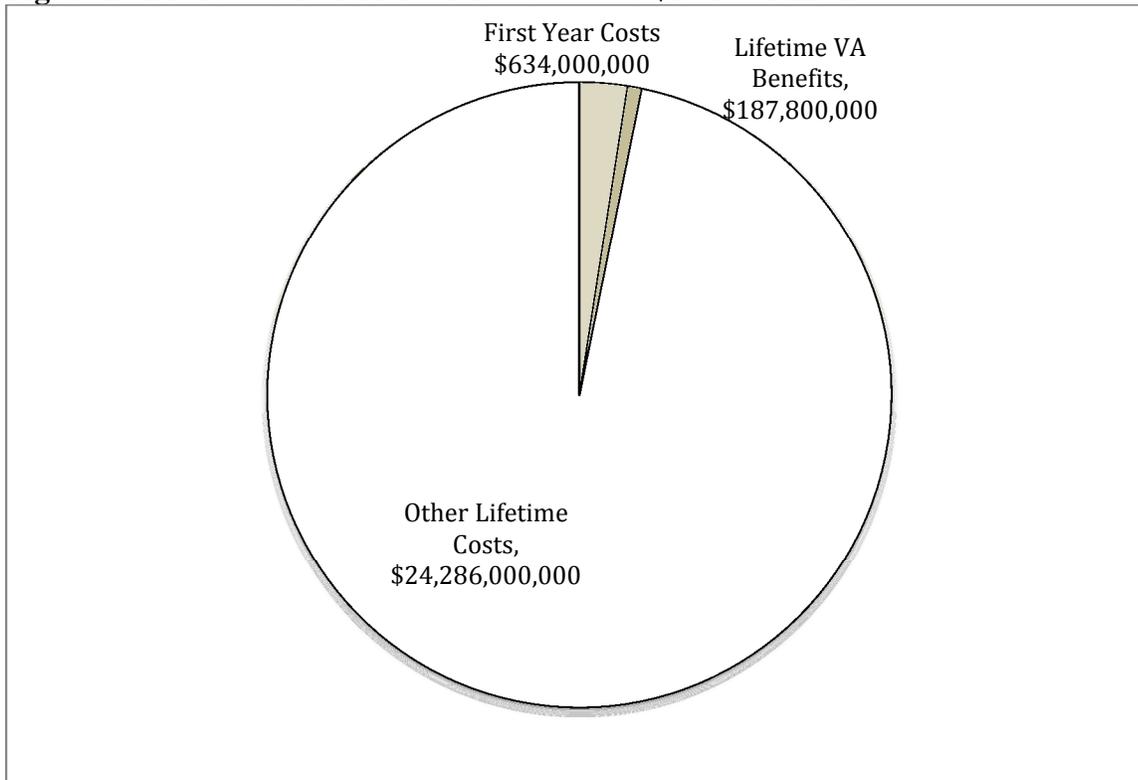
Table 16. Total Annual Cost Summary

<u>Category</u>	<u>Cost (2012 US \$)</u>
All Costs Related to Superficial Injury (Applies to Figure 1 Section A)	10,015,704
Initial Medical Care for Non-Superficial Injury (Applies to Service Members in Figure 1 Sections B1-B3)	46,688,075
All Costs Related to Vision Impairment from Ocular Injury that Does not Result in Bilateral Blindness (Applies to Service Members if Figure 1 Section B2)	353,078,053
All Costs Related to Bilateral Blindness Experienced by Those who Suffer Ocular Injury (Applies to Service Members if Figure 1 Section B2)	29,827,562
All Costs Related to Vision Impairment Associated with Traumatic Brain Injury (Applies to Service Members in Figure 1 Section C)	1,842,880,826
Total	\$2,282,490,221

Total Short-Term and Lifetime Cost of Eye Injury in the Years of Conflict

The costs described above are the average one-year costs based on the average incidence of injury over the time from 2000-2010. As noted above, it is difficult to anticipate whether the next ten years will bring the same level of ocular injury—with the mission in Iraq being complete and the mission in Afghanistan winding down. It is important to note that if we multiply the one-year costs by 11, the total cost to the economy of all ocular injury and vision impairment related to TBI is \$25.107 billion. Of that total, the costs incurred in the first year (all for superficial injury, initial medical care for non-superficial injuries, and rehabilitation for bilateral vision impairment) are \$634 million. This is money that has already been spent. The present value of the projected VA benefits for the remainder of the lives of all service members with ocular injuries in the 11 years under study is \$188 million. The present value of the projected costs to the remainder of the economy over the remaining lifetimes of the service members with eye injuries or vision impairment due to TBI is \$24.286 billion. This last cost is not to the federal government but to the economy and society as a whole. The relative size of these costs is shown in Figure 2.

Figure 2. Distribution of 11 Year Total Cost of \$25.107 Billion



V. LIMITATIONS

No study that attempts to make projections such as these is ever likely to be perfect. There are a number of limitations to this analysis that are worth noting. Each limitation could shift the results, however, we have no reason to expect that the shift would change the order of magnitude from the low billions of dollars per year. The limitations include the following:

- (1) As the diagnosis of TBI is improved, the incidence will change—likely increasing. With a higher prevalence the estimates of the costs would be higher.

- (2) The association between TBI and visual impairment or vision dysfunction when there is not ocular injury is established but there are relatively few data to inform the analysis. The Cockerham et al. (2009) results are similar to results from Brahm et al. (2009). The latter results also suggest that approximately 75% of those with TBI have some vision dysfunction or impairment but they also suggest that around 7% have an ocular injury. In this analysis, if the Cockerham et al. data also counted ocular injury and the numbers were similar, we would find that only approximately 68% of the TBI cases are associated with ocular dysfunction that is not accounted for somewhere else in the model. This decrease of 7% would cut the dollar amount associated with TBI, decreasing it to approximately \$1.65 billion per year. This would not change the order of magnitude of the results, however.
- (3) Our understanding of the relationship between TBI and vision dysfunction is evolving in other ways. In particular, we now have a better idea of how TBI at all levels of severity (and not just among more severe cases) relates to vision dysfunction. This has been incorporated into the analysis. If the moderate, severe, and penetrating levels were the only ones associated with vision dysfunction, then estimated costs would decrease.
- (4) We have only a limited understanding of the impact on families. This is due to a lack of reported results in the United States. The figure of less than \$1,000 per year to represent the impact of one family member's blindness on the remainder of the family seems likely an underestimate.
- (5) We assumed that eligibility for blind rehabilitation through the Department of Veterans Affairs was based on legal blindness. While this is consistent with former VA eligibility rules, the rules have changed to be more inclusive than legal blindness only. The new rules are based on vision dysfunction. These changes in the rules for eligibility for blind rehabilitation within the VA and (and similar changes in the rules for long-term VA benefits (to rules that are more inclusive than only legal blindness) would make the costs higher. However, it is difficult to estimate just how many more veterans would be eligible. The Department of Veterans Affairs estimates that there is approximately a six to one ratio between veterans with low vision who may be eligible and legally blind veterans (http://www.va.gov/BLINDREHAB/BRS_Coordinated_Care.asp accessed on 2 May 2012). However, these calculations are based largely on blindness related to aging rather than injuries in the field (personal communication with Dr. Gregory Goodrich who is a coauthor on the Cockerham et al. paper cited in Section IIB), so we have not incorporated them into the analysis.

References

- Brahm KD, Wilgenburg HM, Kirby J, Ingalla S, Chang CY, Goodrich GL. Visual impairment and dysfunction in combat-injured servicemembers with traumatic brain injury. *Optom Vis Sci.* 2009; 86(7): 817-25.
- Buckingham RS, Whitwell KJ, Lee RB. Cost analysis of military eye injuries in fiscal years 1988-1998. *Mil Med.* 2005; 170(3): 196-200.
- Chapter 8. Final Report for the Veterans' Disability Benefits Commission: Compensation, Survey Results, and Selected Topics. CRM D0016570.A2/Final, August 2007.
- Cockerham GC, Goodrich GL, Weichel ED, Orcutt JC, Rizzo JF, Bower KS, Schuchard RA. Eye and visual function in traumatic brain injury. *J Rehabil Res Dev.* 2009;46(6):811-8.
- Congdon N, O'Colmain B, Klaver CC, Klein R, Muñoz B, Friedman DS, Kempen J, Taylor HR, Mitchell P; Eye Diseases Prevalence Research Group. Causes and prevalence of visual impairment among adults in the United States. *Arch Ophthalmol.* 2004; 122(4): 477-85.
- Fischer H. *U.S. Military Casualty Statistics: Operation New Dawn, Operation Iraqi Freedom, and Operation Enduring Freedom.* 2010. Congressional Research Service. 7-5700. Accessed at <http://www.fas.org/sgp/crs/natsec/RS22452.pdf>.
- Frick KD, Gower EW, Kempen JH, Wolff JL. Economic impact of visual impairment and blindness in the United States. *Arch Ophthalmol.* 2007; 125(4): 544-50.
- Gold MR, Russell LB Siegel JE Weinstein MC. *Cost-effectiveness in health and medicine.* Oxford: Oxford University Press; 1996.
- Hilber DJ. Eye injuries, active component, U.S. Armed Forces, 2000-2010. *MSMR.* 2011; 18(5): 2-7.
- Houtenville AJ. A Comparison of the Economic Status of Working-Age Persons with Visual Impairments and Those of Other Groups – Employment. *JVIB.* 2003; 97(3).
- Islam SS, Doyle EJ, Velilla A, Martin CJ, Ducatman AM. Epidemiology of compensable work-related ocular injuries and illnesses: incidence and risk factors. *J Occup Environ Med.* 2000; 42(6): 575-81.
- Keeffe JE, Chou SL, Lamoureux EL. The cost of care for people with impaired vision in Australia. *Arch Ophthalmol.* 2009 Oct;127(10):1377-81.
- Kuhn F, Morris R, Witherspoon CD, Mann L. Epidemiology of blinding trauma in the United States Eye Injury Registry. *Ophthalmic Epidemiol.* 2006; 13(3): 209-16.

Rein DB, Zhang P, Wirth KE, Lee PP, Hoerger TJ, McCall N, Klein R, Tielsch JM, Vijan S, Saaddine J. The economic burden of major adult visual disorders in the United States. *Arch Ophthalmol.* 2006; 124(12): 1754-60. Erratum in: *Arch Ophthalmol.* 2007; 125(9): 1304.

Stroupe KT, Stelmack JA, Tang XC, Reda DJ, Moran D, Rinne S, Mancil R, Wei Y, Cummings R, Mancil G, Ellis N, Massof RW. Economic evaluation of blind rehabilitation for veterans with macular diseases in the Department of Veterans Affairs. *Ophthalmic Epidemiol.* 2008; 15(2): 84-91.

Thach AB, Johnson AJ, Carroll RB, Huchun A, Ainbinder DJ, Stutzman RD, Blaydon SM, Demartelaere SL, Mader TH, Slade CS, George RK, Ritchey JP, Barnes SD, Fannin LA. Severe eye injuries in the war in Iraq, 2003-2005. *Ophthalmology.* 2008; 115(2): 377-82.