Mortality following Traumatic Brain Injury among Individuals Unable to Follow Commands at the Time of Rehabilitation Admission: A NIDRR TBI Model Systems Study

Running title: Mortality When Unable to Follow Commands

Table of Contents Title: Mortality When Unable to Follow Commands at Rehab Admission

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This is the author's manuscript of the article published in final edited form as:

Greenwald, B. D., Hammond, F. M., Harrison-Felix, C., Nakase-Richardson, R., Howe, L. L. S., & Kreider, S. (2015). Mortality following Traumatic Brain Injury among Individuals Unable to Follow Commands at the Time of Rehabilitation Admission: A National Institute on Disability and Rehabilitation Research Traumatic Brain Injury Model Systems Study. Journal of Neurotrauma, 32(23), 1883–1892. https://doi.org/10.1089/neu.2014.3454

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Abstract

Severe traumatic brain injury (TBI) has been associated with increased mortality. This study characterizes long-term mortality, life expectancy, causes of death and risk factors for death among patients admitted within the National Institute on Disability and Rehabilitation Research (NIDRR) TBI Model Systems Programs (TBIMS) who lack command following at the time of admission for inpatient TBI rehabilitation. Of the 8,084 persons enrolled from 1988 and 2009, 387 from 20 centers met study criteria. Individuals with moderate to severe TBI who received inpatient rehabilitation were 2.2 times more likely to die than individuals in the U.S. general population of similar age, gender and race, with an average life expectancy (LE) reduction of 6.6 years. The subset of individuals who were unable to follow commands on admission to rehabilitation were 6.9 times more likely to die, with an average LE reduction of 12.2 years. Relative to the US general population matched for age, gender and race/ethnicity, these non-command following individuals were over 4 times more likely to die of circulatory conditions, 44 times more likely to die of pneumonia and 38 times more likely to die of aspiration pneumonia. The subset of individuals with TBI who are unable to follow commands upon admission to inpatient rehabilitation are at a significantly increased risk of death when compared to the US general population, and compared to all individuals with moderate to severe TBI receiving inpatient rehabilitation. Respiratory causes of death predominate compared to the general population.

brain injury, chronic; brain injuries; rehabilitation; life expectancy; epidemiology; mortality; disorder of consciousness

Introduction

Traumatic brain injury (TBI) is one of the most common causes of mortality and morbidity in the United States. There are an estimated 52,000 deaths and 275,000 hospitalizations each year due to TBI.[1] The estimated economic cost of TBI in 2010 was approximately $76.5 billion.[2] Fatal TBIs and TBIs that required hospitalization account for approximately 90% of the total TBI medical costs each year. [3,4] Numerous investigations have established that experiencing a moderate-to-severe TBI decreases life expectancy (LE) and increases an individual's risk of death even after survival from the initial injury. [5-9] Large cohort studies have found a 30% mortality rate during the first 6 months after severe TBI. [10,11] Decreased survival rates remain even with advanced age at injury.[9] Higher than expected rates of neuro-medical complications has led to a model of TBI as a chronic disease.[12] Based on standardized mortality ratios, individuals with a TBI are over twice as likely to die when compared with the age, gender, race matched US general population.[5]

Risk factors for decreased survival rates after severe TBI and cause of death after severe TBI are both important variable to investigate and understand. Many causes of death after severe TBI have been established in the literature. Interestingly, age at time of injury has recently been reported to differentiate causes of death. When systematically evaluating causes of death by age at time of injury, younger survivors of TBI (ie, younger than 45 years) have a greater proportion of external mechanisms of

injury, including all unintentional injuries, vehicular injuries, accidental poisoning, homicide, and suicide. This suggests that in this age neurobehavioral consequences of TBI such as impulsivity or behavioral dysregulation may be risk factors for premature death.[9] In contrast, among individuals who were injured after the age of 45 years the most common causes of death included chronic medical conditions such as circulatory and respiratory diseases, conditions that are suggestive of poor overall health or frailty such as pneumonia, aspiration pneumonia, sepsis, and falls, and neurological or neurodegenerative causes such as nervous system diseases (eg, Alzheimer disease) and mental disorders (eg, dementias). [9] The former causes of death in the younger group may be amenable to cognitive or behavioral interventions, while the later causes of death in the older group may be preventable by increased monitoring. [9]

Severe TBI has been associated with poorer outcomes and increased mortality. When looking at a series of 111 adult patients admitted to a neurosurgical program with an initial GCS of 3, 89% of the patients (99) died within 2 to 30 days post injury, 7% (8) survived in a vegetative state and 4% (4) survived longer. [14] Increased severity of TBI (i.e. moderate to severe) has been associated with higher mortality due to seizures, septicemia, pneumonia, and respiratory conditions. [15] Similar to how age at time of injury influenced likely causes of death, it is reasonable to believe that severity of injury, even within the severely injured category, will influence immediate and long-term morbidity and mortality. Length of time after injury to begin following commands is an indicator of the severity of injury. Previous studies have shown that patients who have an inability to follow commands at the time of admission to rehabilitation have an overall 2-fold increase in rehospitalizations in the first year post-injury. [16]

Increased understanding of the relationship between risk factors, causes of death, mortality, and LE after severe TBI and prolonged time to follow commands is important for clinical management and may help guide intervention efforts. For example, clinicians may be able to focus on areas amenable to intervention and related to decreased survival rates (e.g., physical recovery and function).[9] Better understanding causes of death after TBI can lead to increased monitoring for early signs and symptoms associated with known mortality risk categories (e.g., respiratory disease, pneumonia), and may highlight categories that may need chronic management following severe TBI among patients who take a prolonged time to follow commands. Preventable causes of death (e.g., falls, subsequent motor vehicle accidents) may be reduced by increased/reinforced education to caregivers and patients during rehabilitation and afterwards. Education and modified or targeted interventions may also lead to reduced overall costs to the healthcare system. Increased understanding of these variables and the relationship among them may lead to positive individual health and well being outcomes. This research may also help identify research and education priorities, and support the need for services among those living with a TBI.

The purpose of this study was to characterize long-term mortality, LE, causes of death and risk factors for death among persons who lack command following at the time of admission for inpatient TBI rehabilitation, compared to those able to follow commands. An additional aim was to compare demographic, injury and functional status among those who died to those who survived *within* the 2 comparison groups (the group without command following and the group following commands). Finally, mortality in

both groups was compared to those with similar age, gender, race/ethnicity and cause of death in the US general population.

Methods

This study utilizes the TBI Model Systems (TBIMS) National Database (NDB) funded by the US Department of Education via the NIDRR since 1987. The TBIMS NDB contains information on cases treated within the 20 TBIMS centers funded between 1988 and 2012, which are located around the United States.[17] The TBIMS define TBI as damage to brain tissue caused by an external mechanical force as evidenced by medically documented loss of consciousness or posttraumatic amnesia (PTA) due to brain trauma or by objective neurological findings that can be reasonably attributed to TBI on physical examination or mental status examination. Subjects included in the database, in addition, must (1) meet at least 1 of the following criteria for moderate to severe TBI: PTA greater than 24 hours, trauma-related intracranial neuroimaging abnormalities, loss of consciousness exceeding 30 minutes, or a Glasgow Coma Scale (GCS)[18] score in the emergency department of less than 13 (unless due to intubation, sedation, or intoxication); (2) be at least 16 years of age at the time of injury; (3) present to the Model System's acute care hospital within 72 hours of injury; (4) receive both acute hospital care and comprehensive rehabilitation in a designated brain injury inpatient unit within the Model System; and (5) provide informed consent to participate or have a proxy provide consent.[18] Each TBIMS site received Institutional Review Board approval.

For purposes of this study, the NDB as of March 10, 2011, was limited to 8,573 individuals treated within 20 TBIMS sites, with injury dates beginning on October 25, 1988, through December 31, 2008, and follow-up dates or death dates through December 31, 2009. Information in the database was collected during acute care and rehabilitation hospitalization and at 1 year, 2 years, 5 years, and every fifth year thereafter at about the anniversary of injury. The rate of successful follow-up overall years of follow-up is around 80%. [19] TBIMS staff attempted to contact individuals for interview; if they were told that the person had died, the death date was entered in the NDB. If *between follow-up interviews* center staff learned that a participant had expired, the date of death was recorded in the NDB at that time point. Upon learning of a participant death, center staff attempted to obtain the death certificate. Causes of death listed on the death certificate were coded using the *International Classification of Diseases, Ninth Revision* (*ICD-9*), codes. In cases where contact with the participant or a knowledgeable proxy at a routine follow-up interval was not made, center staff attempted to verify the vital status of participants using the Social Security Administration's Death Index (SSDI). If persons were not listed in the SSDI as deceased, and they could not be found, they were reported as lost to follow-up at that time point. Even if a person was reported as lost to follow-up at one scheduled follow-up interview, the staff would attempt to contact the individual at the next scheduled follow-up time point, often with success. For cases reported as lost as of their most recent follow-up (n = 1,158 of 8,573), the TBIMS staff for purposes of this study were asked to again look up cases in the SSDI to determine whether they were alive or had expired. For those previously lost cases that were found in the SSDI as expired, the vital status

was updated in the NDB and the center attempted to obtain the death certificate. Those previously lost cases that were not listed in the SSDI were presumed to be alive at the end of the study period (December 31, 2009). Only deaths occurring after discharge from initial inpatient rehabilitation and before January 1, 2010, were included in the analyses.

Two comparison groups were created based on functional response to motor command at the time of rehabilitation admission: 1) a “command following” group and 2) a “non-command following” group. The non-command following group was defined as cases with a date able to follow simple motor commands after the date of rehabilitation admission (indicating the individual was not able to follow simple motor commands at the time of inpatient rehabilitation admission), and having a Disability Rating Scale (DRS) [20] motor item score not equal to 0 for the rehabilitation admission assessment (meaning that the individual was not obeying commands at the time of rehabilitation admission). Of the 8,573 cases in the national database, 204 cases were missing date able to first follow commands (2.3%), 97 cases were missing DRS score upon rehabilitation admission (1.1%), and 1 case was missing rehabilitation admission date thus 302 (3.5%) individuals were excluded due to insufficient information to determine command following status at time of rehabilitation admission. All other cases were then considered in the command following comparison group.

The data analysis was performed using SAS software, Version 9.3 for Windows (SAS software, Version 9.3 of the SAS System for Windows; SAS Institute Inc, Cary, NC). Descriptive statistics (means for continuous variables and counts and proportions for categorical variables) were used to characterize the study sample.

The Standardized Mortality Ratios (SMRs) were calculated as the observed number of deaths in the study cohort divided by the expected number of deaths in similar individuals from the US general population. The number of expected deaths was calculated by assigning the US mortality rate for a given calendar year for each year post-injury on the basis of sex, race, and age at each annual anniversary of injury. Once rates were assigned for each post-injury anniversary year for each case, these rates were summed for each case. Finally, the cumulated rate was summed over all cases in the population study cohort. For the purposes of this study, the US mortality rates published by the federal government [21] for the calendar year 1999 (the median person-years of follow-up in the study) were used. Statistical significance of the SMR was determined by calculating its 95% confidence interval, which was considered significant if it did not contain 1.0. [22]

A cumulative conditional probability of survival curve was produced. Cumulative conditional probability of survival is based on the idea that the current probability of survival is conditioned on the fact that a person must have survived each of the previous time periods. SMRs were also calculated for specific causes of death. The expected number of deaths in the absence of TBI was calculated using the methodology described previously but using the age-sex-race/ethnicity-specific mortality rates for each cause of death category.[20] In 1999, the federal government transitioned from using *ICD-9* to *ICD-10*, for coding causes of death. The cause of death mortality rates based on *ICD-10* code categories were used to calculate expected deaths for the SMRs, and these were then matched to observed causes of death by *ICD-9* code

categories, because *ICD-9* was used to code the death certificates (see Table 5 for an *ICD-9*/*ICD-10* code category crosswalk).

Comparative LE with and without TBI by age, sex, and race was estimated by applying the overall SMR (for those with TBI) to the latest age-sex-race/ethnicity-specific mortality rates published by the federal government for the most recent year available at the time of this study (calendar year 2007), using the methodology described by DeVivo.[21] The US General Population mortality rates by age, gender and race were multiplied by the overall SMR. This results in the mortality rates or the probabilities of death for individuals with TBI. To obtain the probabilities of life for individuals with TBI, the probabilities of death were subtracted from one. Next, the cumulative probabilities of life were calculated by multiplying the probabilities of life with TBI at a given age by the probabilities of life at the next year's age. Then, this product was multiplied by the probabilities of life with TBI for the following year's age. This method was repeated for each age until age 100. These cumulative probabilities of life with TBI for each age were then summed to obtain estimated years of life expectancy. This method was repeated for each age to determine the estimated life expectancy at that age. It should be noted that this method used a constant SMR for the TBI cohort with advancing age which often results in a slight underestimation of long-term survival probabilities and life expectancy. An average life expectancy reduction was then calculated by averaging the differences between the TBI and non-TBI life expectancies.

Results

Of the 8,084 participants, 387 were observed to not follow commands at the time of rehabiltiation admission, and thus, considered in the non-command following group. The demographic and injury severity charateristics of the entire sample, non-command following group and command following group are summarized in Table 1. The non-command following group tended to be younger, injured as a result of vehicular-related causes, had more days until rehabilitation admission and discharge, and more severe TBI (i.e., lower GCS, longer duration of unconsciousness and PTA).

*****Insert Table 1 Here*****

Mortality data for the comparison groups are summarized in Table 2. This is the mortality for our subjects who survived acute care and came to one of the TBIMS programs for acute rehabilitation instead of a skilled nursing facility or other discharge location. In the non-command following group there were 387 individuals with 50 deaths, with a higher mortality rate of 13% compared to 9.5% in the comparison group ($p = .03$). Death after TBI in all three groups (entire sample, non-command following, and command following) was higher than expected in the general population, with the non-command following group having much higher than expected mortality rate than the other groups. The non-command following group was 6.9 times more likely to die than those in the US general population of similar age, gender and race/ethnicity (compared to 2.1 times greater than expected risk of death in the command following group). On average, LE was reduced more in the non-command following group (LE reduction 12.2 years) compared to average LE reduction of 6.2 years in the command following group.

The average time from injury to death was almost 1 year (361 days) shorter in the non-command following group compared to the command following group. Survival curves for the non-command following and command following groups are displayed in Figure 1. The survival curve for the entire group overlaps with that of the command following group, and therefore is not shown. This finding of earlier time to death in the non-command following group was examined further by assessing the follow-up time period during which the deaths occurred as depicted in Table 3. A greater proportion of individuals in the non-command following group died between inpatient rehabilitation discharge and the one-year post-injury anniversary (36% compared to 21% in the command following group), however the group differences did not reach statistical significance (p=.11).

*****Insert Table 2 Here*****

*****Insert Figure 1 here*****

*****Insert Table 3 Here*****

As summarized in Table 2, the non-command following group was on average younger at the time of death than the comparison group (49.3 years in the non-command following group compared to 61.0 years of age in the command following group). This was further illuminated by examining the survival curves by age at time of injury in the non-command following group (Figure 2) and command following group

(Figure 3). Comparison of these survival curves reveals that with each of the age groups the non-command following group dies sooner following rehabilitation discharge than their respective command following age group, most markedly noted for the two youngest age groups.

*****Insert Figure 2 Here*****

*****Insert Figure 3 Here*****

Within and between each group, those who survived were compared to those who died during the study on measures of age, injury and function as summarized in Table 4. Those in non-command following group that died tended to be younger, had more days until rehabilitation admission and discharge, more severe TBI, less functional independence, and greater disability, compared to those in the command following group that died. Those who died were on average older at injury than those who survived in each of the comparison groups. There was not a substantial difference in rehabilitation admission Functional Independence Measure (FIM) [23] and DRS scores between those who survived and those who die within each comparison group. Of note, in each comparison group those who died had on average worse discharge FIM and DRS scores than those who survived throughout the study period, despite a lack of substantial differences in function at the time of admission.

*****Insert Table 4 Here*****

Table 5 provides detail about causes of death by comparison group with frequency of deaths within subcategories as well as the broader categories of cause of death. Of note is that specific cause of death is unknown in 30% of those in the non-command following group and 14% in the command following group. Causes of death following TBI for each group were compared to the general population of similar age, gender and race/ethnicity as summarized in Table 6. The non-command following group had higher SMRs for circulatory, all respiratory, and pneumonia specific causes than the command following group. In particular, the non-command following group was over four times more likely to die of circulatory conditions, 44 times more likely to die of pneumonia, and 38 times more likely to die of aspiration pneumonia than those in the general population of similar age, gender and race/ethnicity. There were no deaths due to digestive causes in the non-command following group.

*****Insert Table 5 Here*****

*****Insert Table 6 Here*****

Discussion

This study is consistent with prior work demonstrating that individuals with TBI have a higher rate of mortality compared to similar persons in the general population.[5,7-9,24-25] However, this is the first study to demonstrate that mortality risk and overall LE reduction varies across injury severity levels specifically with reference to non-command following samples. Within the study sample of individuals with TBI treated in the TBIMS comprehensive rehabilitation programs, individuals classified as non-command following upon rehabilitation admission demonstrated a higher mortality rate (13% vs 9.5%), a higher overall SMR (6.9 vs 2.14), and greater reduction in overall average LE (12.2 years vs 6.2 years) compared to those who were command following upon rehabilitation admission. Among those that died, time to death was on average 1 year earlier in the non-command following cohort (Mean age at death = 49 years) compared to the command following cohort (Mean age at death = 61 years) despite being significantly younger in age. In addition to overall earlier death, a greater disproportion of deaths between the 2 groups was observed between rehabilitation discharge and 1-year post-injury relative to other follow-up intervals (Table 3). This finding is consistent with recent work that highlights greater number of rehospitalizations in the first year post-injury for non-command following patients compared to those with lesser injury severity and command following status upon rehabilitation admission. [16]

Circulatory disease was the top cause of death in all comparison groups. External causes of injury (vehicular, fall, etc.) are new injuries subsequent to the injury that caused the index TBI. These were the second leading cause of death for the entire and command following groups but this was an uncommon cause of death in the non-

command following group. Respiratory (including pneumonia and aspiration pneumonia) and infectious disease were the second and third leading causes of death respectively in the non-command following group. In the non-command following group it can be speculated that the low rates of external causes of death and the high rates of respiratory and infectious causes of death are a reflection of the poor functional improvement relative to the rest of the sample. Preventable causes of death from falls and motor-vehicle crashes are important points of education to caregivers in the rehabilitation process and for providers managing the long-term needs of TBI patients.

Age and injury severity indices within subgroups differentiated those at risk for mortality during the study period. Across subgroups, older age and lower physical functioning on the FIM at rehabilitation discharge were associated with mortality status. However, within the non-command following cohort, additional indices at rehabilitation discharge (Cognitive FIM, and DRS Total Score) were associated with higher mortality despite comparable functioning and injury severity (i.e., emergency department GCS, rehabilitation admission FIM, DRS) at earlier time points. In the non-command following group lower functional gains during rehabilitation may therefore be a marker for higher mortality after discharge from rehabilitation. Poorer physical functioning has previously been associated with shortened LE at any time after moderate to severe TBI. [26]

Persons with TBI have higher SMRs for many causes of death including pneumonia, sepsis, and seizures. This study found substantially higher SMRs for these conditions in the non-command following cohort; however, the small non-command following numbers in these categories rendered the results non-significant. Higher SMRs were also observed in the other causes of death (i.e., circulatory, respiratory).

Higher SMRs due to infectious causes is consistent with Nakase-Richardson and colleagues work showing infection was the most common reason for rehospitalization in the first year after injury and remained a common reason for rehospitalizations for the five years post-injury follow-up.[16] Immune dysfunction in the acute phase has been recognized as a consequence of TBI. This may be related to trauma induced glucocorticoid secretion and poorly understood neuroinflammation.[27-29] Individuals who remain physically dependent may be more likely to be at higher risk of community acquired and nosocomial infections. They also may acquire from prolonged hospitalizations, and are at higher risk of pressure sores, aspiration pneumonia, and require indwelling urinary catheters. The high rate of death secondary to aspiration pneumonia stands out as a high priority for studies to improve short and long term care. In each comparison group those who died were less functional on average at the time of rehabilitation discharge, indicating this may serve as a marker for greater surveillance. Further study is needed to assess mortality risks in those with non-command following, and mortality specifically among those who fail to recover command following during inpatient rehabilitation. Further study is needed to determine if a longer inpatient rehabilitation stay might increase physical functioning as determined by the FIM scores at discharge. If so, this could have implications for clinical management of future patients.

Other causes of death described may not fully capture the medical comorbidities under management when death occurs. As such, the broad categories of death reported in this study can help inform general areas that may need chronic management following TBI especially in those who experienced prolonged non-

command following. Finally, these numbers do not indicate when decisions were made for palliative care and subsequent termination of life.

Study Strengths and Limitations

The TBIMS NDB provided the opportunity to study a relatively large sample size of individuals not following commands at the time of acute inpatient rehabilitation, extensive demographic, injury, and outcome data, and a high rate of vital status follow-up. Given that the individuals included in the study were all treated at TBIMS, the study may be limited in generalizability to individuals with TBI receiving inpatient rehabilitation treatment elsewhere. However, Corrigan and colleagues found TBIMS NDB to be representative of patients receiving inpatient rehabilitation for TBI in the United States.[30,31] Another consideration is that the findings of the present study represent a select group of individuals who survived injury and acute care hospitalization and received inpatient rehabilitation. This is important as it is currently common for individuals who do not follow commands to either not qualify or not be provided the opportunity to receive any inpatient rehabilitation. Additional research should be conducted, to learn about the mortality among those who do not receive or qualify for inpatient rehabilitation services. For example, it will be important to assess life expectancy and mortality risk factors for those not following commends at the time of acute care discharge who are sent to a longterm acute care hospital or a skilled nursing facility.

The TBIMS only collects information during rehabilitation and then periodically after that. Additional information closer to death may further elucidate risk factors for death. Prospective collection of lifestyle factors including smoking, alcohol, drugs, diet,

exercise frequency should also be looked at for their contribution to increased mortality. Cause of death is based on death certificates. The accuracy and comprehensiveness of the completion of the death certificate was not verified. Cause of death was unknown in 30% of those in the non-command following group and 14% in the command following group. Because cause of death was unknown in so many cases, particularly in the non-command following group these presently listed causes of death may limit identification of cause of death trends. Lastly, the TBIMS has only been in existence since 1987, and thus, the follow-up period for this study was around 20 years which is relatively short in a lifetime. As TBIMS data continues to be collected, this limitation will lessen.

Limitations of this study include the operational definition of non-command following status to include persons who do not follow commands upon rehabilitation admission. Although the study verified command following status across two measurement indices in the TBIMS data collection structure, the reader should bear in mind that not following commands is a dynamic situation, particularly in the weeks immediately after injury. Many of the individuals classified as non-command following at the time for rehabilitation admission progressed as expected to a higher level of function prior to discharge. [32,33] The medical status of the non-command following is highly complex. There are many reasons why an individual may lack command following after TBI (e.g., concurrent anoxic insult, impaired arousal, apraxia, and aphasia). Individuals who are non-command following at admission often evolve to different functional levels. As such, these data are interpreted as hypothesis generating for future studies. The study findings point to issues that deserve further study and greater surveillance. Additional data regarding the complexity of the patients and the care each received may

be helpful. For example, TBI related illnesses (e.g., epilepsy, motor function, contractures, pressure ulcers), severity of non-TBI injuries, complications incurred during acute hospitalization, infections, continued use of tracheostomy and percutaneous gastric feeding tube, change in social situation as a result of the injury (i.e. divorce, discharge from inpatient rehabilitation to skilled nursing facility).

Conclusions

This study provides new insight into mortality risks and causes for patients who are unable to follow commands on admission to rehabilitation. This select group of patients are at a significantly higher risk of death compared with both the general population and patients who suffered moderate to severe TBI but were following commands on admission to rehabilitation. Lower functional gain during rehabilitation was associated with higher long-term mortality in this group. Respiratory and circulatory conditions were the primary causes of death in this group. Examining the associations and causes of increased mortality may aid us in lowering long term mortality in this group. Primary prevention can include long term follow-up by specialists familiar with the unique medical issues this group faces. This should include education for individuals with TBI and their family members on monitoring for and seeking treatment for signs of infection and respiratory symptoms and receiving the usual preventive care services aimed at circulatory diseases. Monitoring by clinicians with knowledge regarding the long-term care of this group should include the evaluation over time of additional

physical or speech therapy to maintain mobility and decrease aspiration risk and secondarily decrease mortality is this high risk group.

Acknowledgments

This work was supported, in part, by grants from the National Institute on Disability and Rehabilitation Research, Office of Special Education Services, Department of Education to the Traumatic Brain Injury Model Systems National Data and Statistical Center at Craig Hospital (H133A110006); Indiana University School of Medicine (H133A120085) and Mount Sinai School of Medicine (H133A100284).The Polytrauma Rehabilitation Center Traumatic Brain Injury Model System Collaboration funded through an Interagency Agreement between the Department of Veterans Affairs and the Department of Education, National Institute on Disability and Rehabilitation Research, and VA HSRD; 1 I50 HX001233-01 & SDR 13-228. Although the contents of this manuscript were developed under a grant from the Department of Education, the manuscript contents do not necessarily represent the policy of the Department of Education, and should not assume endorsement by the Federal Government.

Author Disclosure Statement

No competing financial interests exist for Brian D. Greenwald, Flora M. Hammond, Cynthia Harrison-Felix, Risa Nakase-Richardson Laura L. S. Howe and Scott Kreider.

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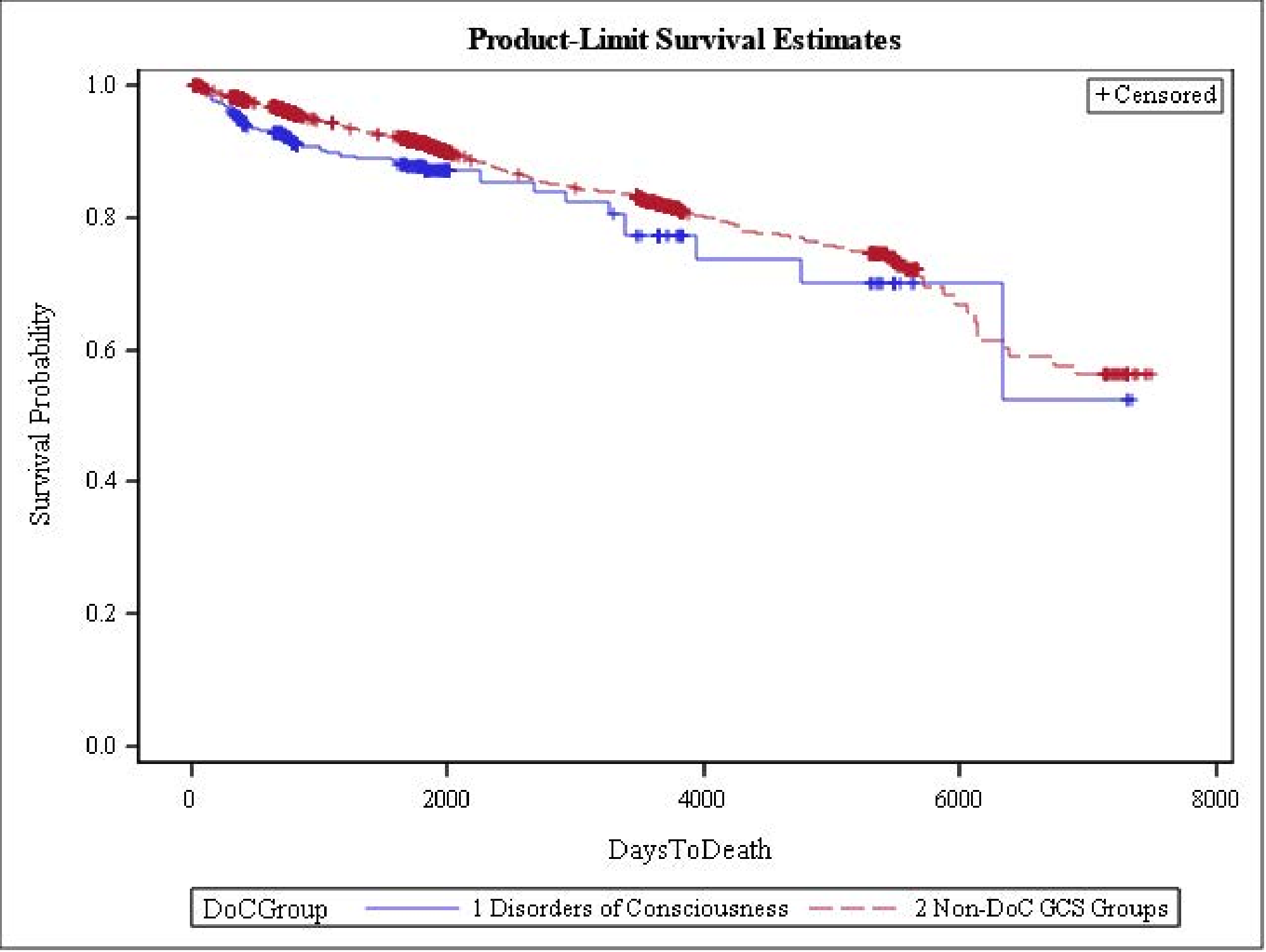
Figure Legends

Figure 1: Survival Curves for Non-Command Following Group and Command Following group

Figure 2: Survival Curve by Age for the Non-Command Following Group

Figure 3: Survival Curve by Age for the Command Following Group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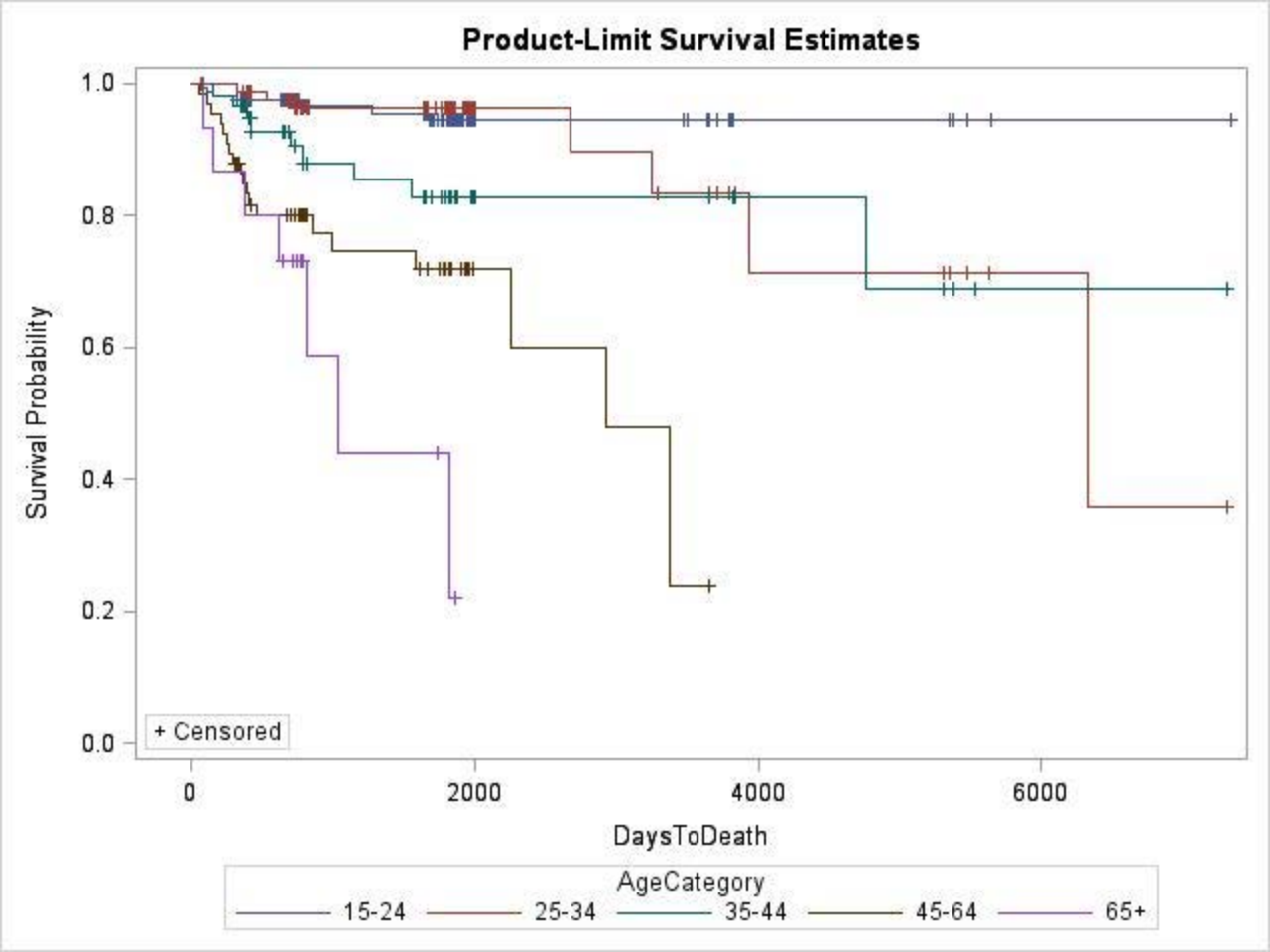
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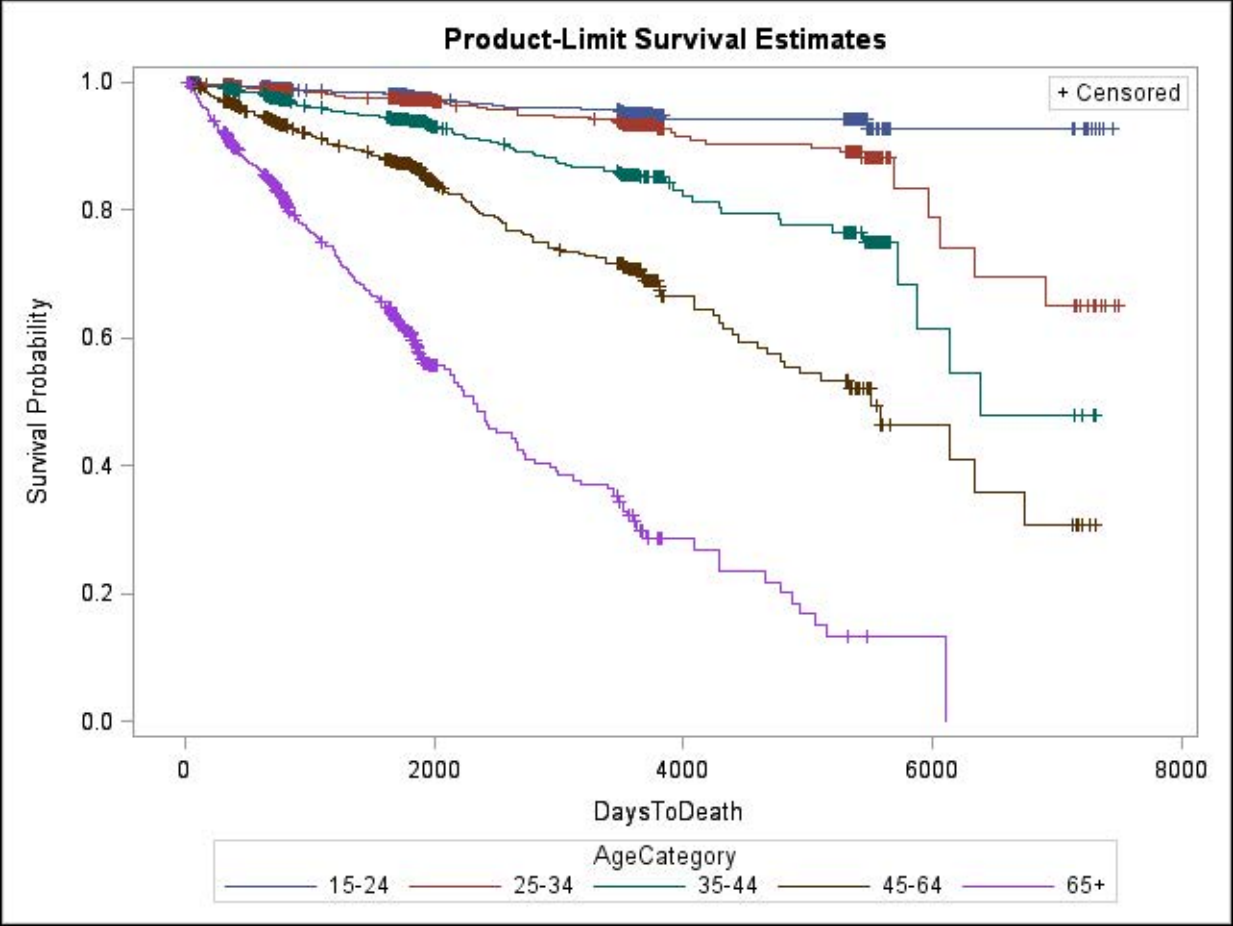
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Tables

Table 1: Demographic and Injury Characteristics by Comparison Group

	Entire Sample n = 8,084	Non-Command Following Group n = 387	Command Following Group n = 7,697	Significance p-value*
Gender - % male	74.1%	73.1%	74.1%	.66
Race				.85
-Black	21.1%	22.0%	21.1%	
-Asian	2.5%	1.8%	2.6%	
-Hispanic	8.1%	8.5%	8.3%	
-Other	1.4%	1.3%	1.4%	
-White	66.6%	66.4%	66.6%	
Cause of Injury				**.009**
-Pedestrian	7.2%	10.6%	7.0%	
-Sports	1.5%	1.6%	1.5%	
-Falls	21.1%	11.4%	21.3%	
-Violence	13.5%	8.5%	13.8%	
-Other	1.7%	1.6%	1.7%	
-Vehicular	55.2%	66.4%	54.7%	
Mean age at Injury (years)	38.82 (SD 18.24)	32.63 (SD 15.31)	39.13 (SD 18.32)	**<.0001**
Mean days from injury to rehabilitation admission	20.89 (SD 16.73)	32.27 (SD 21.5)	20.17 (SD 16.12)	**<.0001**
Mean days from injury to rehabilitation discharge	48.69 (SD 35.13)	96.15 (SD 52.54)	46.13 (SD 32.24)	**<.0001**
Mean days unconscious	8.52 (SD 14.12)	47.82 (SD 28)	7.20 (SD 11.23)	**<.0001**
Mean GCS at emergency room admission	9.39 (SD 4.46)	5.18 (SD 3.06)	9.58 (SD 4.41)	**<.0001**
Mean days of posttraumatic amnesia	33.6 (SD 33.23)	88.89 (SD 48.73)	30.72 (SD 29.52)	**<.0001**
Mean years in study		4.36 years	4.7 years	

*Bold p-values indicate a statistically significant difference between the non-command following group and the command following group.

Table 2: Mortality by Comparison Group

	Entire Sample n = 8,084	Non-Command Following Group n = 387	Command Following Group n = 7,697
Observed deaths	781 (9.7%)	50 (12.9%)	731 (9.5%)
Expected deaths	348	7	341
Standardized Mortality Ratio (SMR)	2.24	6.9	2.14
SMR Upper Confidence Limit (CL)	2.09	4.99	1.99
SMR Lower CL	2.40	8.81	2.30
Mean Life Expectancy reduction	6.6 years	12.2 years	6.2 years
Mean days to death	1,462.27 (SD 1,382.5)	1,124.62 (SD 1,367.64)	1,485.37 (SD 1,381.42)
Mean age at death	60.24 (SD 18.98)	49.30 (SD 17.09)	60.99 (SD 18.88)

Table 3: Death Occurrence by Follow-Up Time Interval by Comparison Group

Time Period of Death Occurrence for those who Died	Entire Sample n = 781	Non-Command Following Group n = 50	Command Following Group n = 731
Died between rehabilitation discharge & 1 Year post-injury	171 (22%)	18 (36%)	153 (21%)
Died between 1 & 2 years post-injury	141 (18%)	10 (20%)	131 (18%)
Died between 2 & 5 years post-injury	236 (30%)	12 (24%)	224 (31%)
Died between 5 & 10 years post-injury	167 (21%)	7 (14%)	224 (22%)
Died after 10 years post-injury	66 (8%)	3 (6%)	63 (9%)

Table 4: Age, Injury Characteristics and Function by Survival Status for Comparison Groups

	Entire Sample		Non-Command following		Command following	
	Alive	Died	Alive	Died	Alive	Died
Mean age at Injury (years)	36.96	56.21	30.62	46.16	37.27	56.89
Mean days injury to rehabilitation admission	20.77	22.05	34.50	40.44	20.11	20.79
Mean days injury to rehabilitation discharge	48.09	54.33	96.27	95.38	45.77	51.52
Mean GCS on Emergency Room Admission	9.21	10.85	5.01	6.12	9.39	11.16
Mean FIM Motor Admission	37.41	33.78	14.36	14.57	38.53	35.17
Mean FIM Motor Discharge	69.25	59.92	39.14	24.02	70.72	62.42
Mean FIM Cognitive Admission	7.87	7.5	1.65	2.81	7.70	7.35
Mean FIM Cognitive Discharge	24.39	21.54	13.42	8.5	24.93	22.41
Mean DRS Admission	12.58	14.26	23.89	22.55	12.03	13.69
Mean DRS Discharge	6.05	8.1	13.95	19.01	5.67	7.34

All comparisons between the non-command and command following groups for all characteristics included in this table, within those who died, and within those who were alive at the end the study, were all statistically significant ($p = <.0001$).

Table 5: Cause of Death Frequencies by Comparison Group

	Entire Sample		Non-Command Following Group		Command Following Group	
Cause of Death by Organ System (ICD-9 Codes)	**Freq**	**Pct**	**Freq**	**Pct**	**Freq**	**Pct**
Circulatory: (390-459)	**172**	**26.02%**	**10**	**28.57%**	**162**	**25.88%**
Other heart disease (420-429)	51	7.72%	4	11.43%	47	7.51%
Ischemic heart disease (410-414)	54	8.17%	5	14.29%	49	7.83%
Cerebrovascular disease (430-439)	31	4.69%	1	2.86%	30	4.79%
Hypertensive disease (401-405)	18	2.72%	0	0.00%	18	2.88%
Arterial diseases (440-449)	9	1.36%	0	0.00%	9	1.44%
Pulmonary circulation diseases (415-417)	4	0.61%	0	0.00%	4	0.64%
Venous diseases (451-459)	5	0.76%	0	0.00%	5	0.80%
External causes of injury: (E800-E999)	**119**	**18.00%**	**2**	**5.71%**	**117**	**18.69%**
Vehicular (E800-E848)	24	3.63%	1	2.86%	23	3.67%
Accidental poisonings (E850-E869)	28	4.24%	0	0.00%	28	4.47%
Homicide (E960-E969)	20	3.03%	0	0.00%	20	3.19%
Fall (E880-E888)	19	2.87%	1	2.86%	18	2.88%
Suicide (E950-E959)	15	2.27%	0	0.00%	15	2.40%
Injury of unknown intent (E980-E989)	6	0.91%	0	0.00%	6	0.96%
Other accidents (E916-E928)	3	0.45%	0	0.00%	3	0.48%
Submersion, suffocation (E910-E915)	2	0.30%	0	0.00%	2	0.32%
Adverse effect of treatment (E934)	1	0.15%	0	0.00%	1	0.16%
Fire, Flames (E890)	0	0.00%	0	0.00%	0	0.00%
Medical complication (E879)	1	0.15%	0	0.00%	1	0.16%
Other external causes of injury	0	0.00%	0	0.00%	0	0.00%
Respiratory: (460-519)	**108**	**16.34%**	**8**	**22.86%**	**100**	**15.97%**
Pneumonia (480-486)	52	7.87%	5	14.29%	47	7.51%
Aspiration Pneumonia (507)	30	4.54%	1	2.86%	29	4.63%
Other respiratory diseases	13	1.97%	0	0.00%	13	2.08%
COPD and allied conditions (490-496)	13	1.97%	2	5.71%	11	1.76%
Neoplasm: (140-239)	**82**	**12.41%**	**1**	**2.86%**	**81**	**12.94%**
Respiratory (160-169)	26	3.93%	1	2.86%	25	3.99%
Other/unspecified site (190-199)	20	3.03%	0	0.00%	20	3.19%
Digestive organs (150-159)	12	1.82%	0	0.00%	12	1.92%
Lymphatic/hematopoietic (200-208)	8	1.21%	0	0.00%	8	1.28%
Genitourinary (179-189)	5	0.76%	0	0.00%	5	0.80%
Oral (140-149)	4	0.61%	0	0.00%	4	0.64%
Bone, breast (170-176)	2	0.30%	0	0.00%	2	0.32%
Uncertain behavior/unspecified nature (235-	4	0.61%	0	0.00%	4	0.64%

239) Neuroendocrine (209)	1	0.15%	0	0.00%	1	0.16%
Infectious disease: (001-139)	**54**	**8.17%**	**4**	**11.43%**	**50**	**7.99%**
Sepsis (038)	46	6.96%	4	11.43%	42	6.71%
Other Infectious Disease	8	1.21%	0	0.00%	8	1.28%
Other signs, symptoms, ill-defined conditions: (780-799, not 780.3)	**5**	**0.76%**	**2**	**5.71%**	**3**	**0.48%**
Nervous System: (320-389)	**25**	**3.78%**	**2**	**5.71%**	**23**	**3.67%**
Hereditary and degenerative CNS diseases (330-337)	14	2.12%	1	2.86%	13	2.08%
Other nervous system diseases	11	1.66%	1	2.86%	10	1.60%
Digestive: (520-579)	**22**	**3.33%**	**0**	**0.00%**	**22**	**3.51%**
Seizure: (780.3)	**20**	**3.03%**	**3**	**8.57%**	**17**	**2.72%**
Mental Disorders: (290-319)	**16**	**2.42%**	**2**	**5.71%**	**14**	**2.24%**
Endocrine, immune, etc.: (240-279)	**15**	**2.27%**	**1**	**2.86%**	**14**	**2.24%**
Genitourinary system: (580-629)	**16**	**2.42%**	**0**	**0.00%**	**16**	**2.56%**
Diseases of the skin, subcutaneous, connective tissue: (680-739)	**3**	**0.45%**	**0**	**0.00%**	**3**	**0.48%**
Diseases of blood: (280-289)	**3**	**0.45%**	**0**	**0.00%**	**3**	**0.48%**
Congenital anomalies: (747)	**1**	**0.15%**	**0**	**0.00%**	**1**	**0.16%**
Unknown cause	120	15%	15	30%	105	14%
Total deaths	781		50		731	
Total cases	8084		387		7697	

Table 6: Standard Mortality Ratios by Cause of Death by Comparison Group*

	Full Sample			Non-Command Following Group			Command Following Group		
Cause	**SMR**	**Lower**	**Upper**	**SMR**	**Lower**	**Upper**	**SMR**	**Lower**	**Upper**
Circulatory	**1.3**	1.11	1.49	**4.58**	1.74	7.41	**1.25**	1.05	1.44
External	**3.58**	2.94	4.23	1.45	-0.56	3.47	**3.67**	3.01	4.34
Respiratory	**3.61**	2.93	4.29	**17.81**	5.47	30.15	**3.39**	2.73	4.06
Pneumonia	**6.37**	4.64	8.11	**44.28**	5.47	83.1	**5.84**	4.17	7.51
Aspiration Pneumonia	**14.11**	9.06	19.16	**38.04**	36.52	112.6	**13.81**	8.79	18.84
Sepsis	**10.32**	7.34	13.3	49.54	0.99	98.1	**9.59**	6.69	12.5
Nervous System	**2.42**	1.47	3.37	12.61	-4.87	30.09	**2.26**	1.34	3.18
Digestive	**1.76**	1.03	2.5	NA	NA	NA	**1.81**	1.05	2.56
Seizures	**35.29**	19.82	50.75	133.74	-17.6	285.09	**31.23**	16.38	46.08
Mental	**2.71**	1.38	4.04	18.37	-7.09	43.84	**2.42**	1.15	3.69

*Bold SMRs are statistically significant