Comorbidities, Health Services Utilization and Costs by Mild Traumatic Brain Injury Exposure: A CENC Study

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CENC
Chronic Effects of Neurotrauma Consortium

Disclaimer

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Manuscript In Process
Comparing Mild Traumatic Brain Injury Groups for Healthcare Service Utilization and Costs over 14 Years: A Chronic Effects of Neurotrauma Consortium (CENC) Study

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Tank Blast Exposure

Artillery Exposure

Mine Clearing Line Charge

Outline

- Background
- Objective
- Methods
- Results
- Discussion
- Questions

Background
Traumatic Brain Injury (TBI)[1]

- An event in which an external force such as a bump, blow, or jolt to the head disrupts the normal function of the brain and causes immediate alteration of consciousness.

- Categorized as mild, moderate, or severe, based on the length of time of lost or altered consciousness, or post-traumatic amnesia, at the time of the event.[2]

- Associated with physical, cognitive, behavioral and emotional dysfunction, including personality changes and depression.[1]

Background
US Military Service Members/Veterans

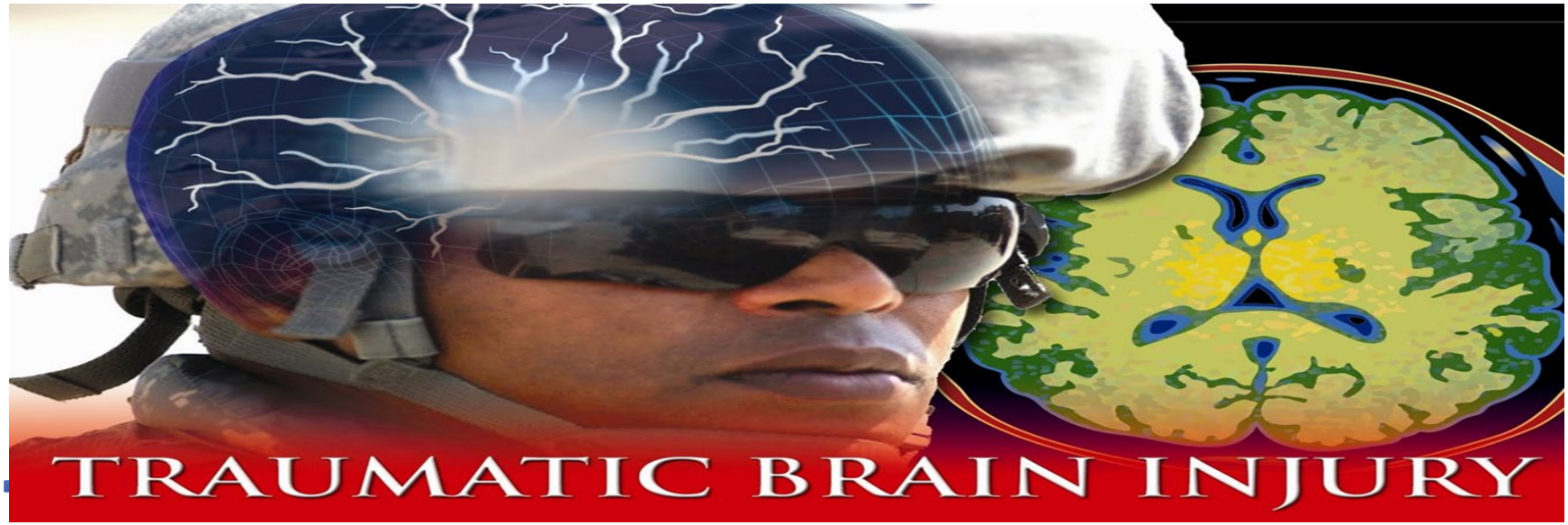
- Since 2000, ~384,000 Service Members diagnosed with TBI.[3]
  - 82% categorized as mild TBI (mTBI), also known as concussion.

- While deployed, at increased risk for:[4,5]
  - Blast-related (BR) Injuries: improvised explosive devices (IEDs), land mines, mortar rounds, and rocket-propelled grenades.
  - Non-blast-related (NBR) Injuries: motor vehicle accidents, falls, assaults

- Many OEF/OIF/OND combat veterans who incurred ≥ 1 mTBIs experience persistent symptoms for which they are seeking healthcare, but administrative data does not contain mechanism.[6-9]

Objective

- To compare Veterans Health Administration (VHA) health services utilization and costs by mTBI exposure (BR vs. NBR vs. no mTBI) among VHA-using OEF/OIF/OND Veterans enrolled in the CENC Longitudinal cohort study.



CENC Researcher
Dr. Ann McKee has detected Chronic Traumatic Encephalopathy (CTE) in 66/102 Veteran Brains

Poll Question

What is your interest in TBI?

- Clinical Provider
- Compensation and Pension Provider
- Researcher
- Leader/Administrator
- Policymaker

Methods
Setting and Participants
CENC Longitudinal Cohort Study

- Enrollment began in 2015 (Walker et al 2016)[10]
- 4 VA Medical Centers: Houston, TX; Richmond, VA; San Antonio, TX; and Tampa, FL
- Eligibility: (1) ≥18 years, (2) combat deployed to OEF/OIF/OND after 2001, and (3) exposed to combat (based on scores of ≥1 on any item from the Deployment Risk and Resiliency Inventory Section D (DRRI-2-D)
- Excluded histories of: (1) moderate/severe TBI or (2) major neurologic or psychiatric disorder that significantly decreased daily functioning

Methods
Identifying mTBI

- Lifetime potential concussive events (PCE)
  - Assessed using a modified version of the Ohio State University TBI Identification Method (OSU TBI-ID).[11]

- Virginia Commonwealth University Retrospective Concussion Diagnostic Interview (VCU rCDI)
  - Used to potentially diagnose each BR and NBR PCE as an mTBI based on the DoD/VA common definition. (Walker et al. 2015)[12]

Methods
Group Classification and Variables

- Groups
  - BR mTBI (could include NBR TBI history)
  - NBR mTBI (excluded BR TBI history)
  - no MTBI
- Military and mTBI-related Variables of Interest

Lifetime mTBI (yes/no)	Total # PCEs
Total # mTBIs	Total # Controlled detonations
Mechanism of mTBI (BR, NBR)	Total # Uncontrolled detonations
Date of first and last mTBI	

Methods
Participant Outpatient Utilization and Cost Data

- VHA outpatient visit and cost data: requested from VINCI.[13]
  - Outpatient visit data: managed by VIReC[14]
  - Cost data: managed by HERC[15]

- Outpatient event dataset: Clinic stop codes, diagnosis codes, services/procedures performed by provider, and provider codes[14]

- Dataset: Restricted to CENC participants with a record of VA outpatient healthcare utilization between 2002-2017, and the identifiers (i.e., SSN) necessary to link CENC and VA records.

Methods
Participant Outpatient Utilization and Cost Data (continued)

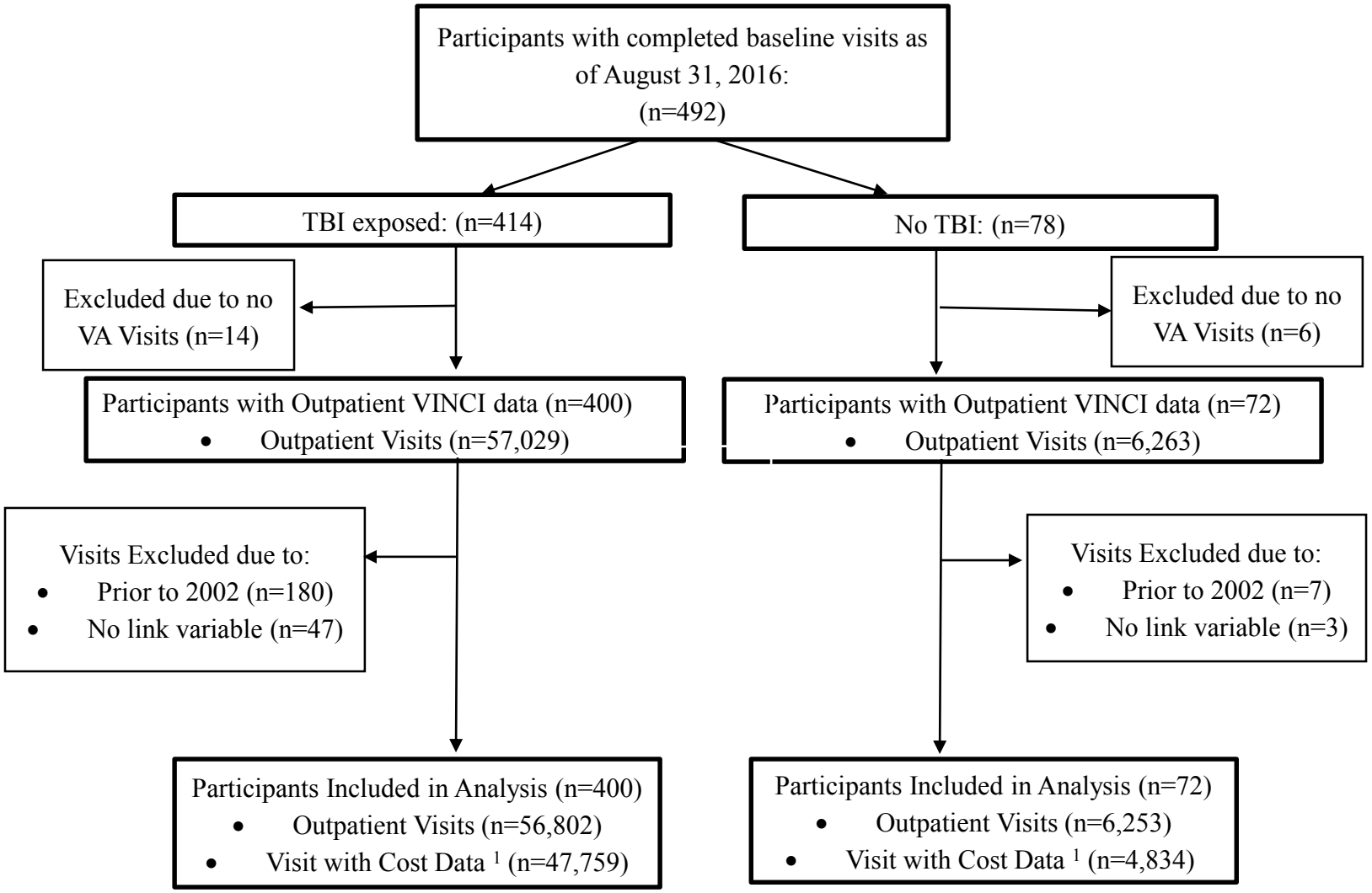
- Estimated by HERC using actual cost data from VA facilities and estimates provided by Medicare using the relative values of all Current Procedures and Terminology (CPT) codes assigned to the visit.[15]
  - Costs then converted to 2018 dollar values using the US Department of Labor Consumer Price Index (CPI) Inflation Calculator.[16]

- To measure outpatient VA utilization and costs, we used the primary clinic stop code in the outpatient event dataset to categorize type of care (e.g., Polytrauma/TBI, Neurology, Mental Health)[17]

- Annual outpatient visit data ranged from 2002-2017; annual outpatient cost data ranged from 2002-2016.

- VINCI data without a linking variable between the visit and cost data were excluded from the analysis.

Figure 1. CONSORT Diagram



[1]Cost data was not available for visit that occurred in 2017

Methods
Diagnoses Assessed

1. Headache
2. Lower back pain
3. PTSD
4. Depression
5. Anxiety
6. Bipolar disorder
7. Psychoses
8. Alcohol dependence and abuse
9. Substance abuse other than alcohol
10. Nicotine dependence

Based on Yoon et al. 2017(HERC)[18]

Methods
VHA Outpatient Clinics Assessed

1. Primary Care
2. Mental Health
3. Polytrauma/TBI
4. Other Rehabilitation
5. Specialty Care
6. Neurology
7. Orthopedics
8. Pain
9. Audiology
10. Diagnostic
11. Imaging
12. Emergency or Urgent Care
13. Other

Based on Taylor et al. 2015[17]

Analyses

- Military characteristics and Diagnoses
  - Stratified by presence and type of mTBI exposure (BR, NBR, no mTBI)
  - Mean and median (interquartile range) for continuous variables
  - Frequency and percentage for categorical variables

- Differences in characteristics and prevalence of diagnoses across groups tested via: Kruskal-Wallis, Chi-square, or Fisher's Exact test

Analyses (continued)

- A Bonferroni correction was used to control the Type 1 error rate at $\alpha=0.05$ to allow for pairwise testing of differences in military characteristics and diagnoses between each of the mTBI categories.

- Site-adjusted annual outpatient visits, including 95% confidence intervals (CIs) for each category of care, were generated using a negative binomial model, due to overdispersion around zero of the counts of visits for many of the care categories.

- Site-adjusted annual outpatient costs, including 95% CI for each category of care, were generated using a generalized linear model (GLM) with a Gamma distribution for overall outpatient VHA costs.

Analyses (continued)

- For individual service category annual cost estimates, a GLM with a Tweedie distribution was used.

- The Tweedie distribution has nonnegative support and can have a discrete mass at zero, making it useful to model responses with a mixture of zeros and positive values, which was the observed distribution for most individual service costs in our dataset.[19,20]

- To obtain annual outpatient visit and cost estimates, each model included an offset function, which was defined as the log of the denominator. The denominator was derived by counting the total number of years in which the participant had ≥1 outpatient visit.

Table 1. Military Characteristics and Experiences, by mTBI Group

	No mTBI (N=72)	NBR mTBI (N=193)	BR mTBI (N=207)
DRRI-2 Combat Score[K]			
Mean (std)	30.3 (12.6)	32.3 (11.9)	48.1 (15.4)
Median	28.0 (20.0, 38.0)[a]	29.5 (23.0, 41.5)[a]	48.0 (36.0, 60.0)[b]
Min, Max	16, 71	17, 72	18, 89
Number Combat Deployments[K]			
Mean (std)	1.9 (1.2)	2.2 (1.6)	2.3 (1.7)
Median (IQR)	1.0 (1.0, 3.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)
Min, Max	1, 5	1, 10	1, 12
Years in Military[K]			
Mean (std)	15.5 (9.6)	15.2 (9.4)	13.1 (8.4)
Median(IQR)	14.0 (6.0, 23.0)	14.0 (6.0, 22.0)	11.0 (6.0, 20.0)
Min, Max	2, 36	3, 39	2, 38
Total # of Controlled Detonations[K]			
Mean (std)	22.8 (36.8)	20.5 (32.9)	34.6 (39.6)
Median(IQR)	3.0 (0.0, 23.0)[a]	3.0 (0.0, 25.0)[a]	15.0 (2.0, 76.0)[b]
Min, Max	0, 100	0, 100	0, 100
Total # Uncontrolled Detonations[K]			
Mean (std)	1.1 (1.1)	0.9 (1.1)	2.6 (1.5)
Median(IQR)	1.0 (0.0, 2.0)[a]	1.0 (0.0, 1.0)[a]	2.0 (2.0, 3.0)[b]
Min, Max	0, 4	0, 5	1, 11

[F] Fisher Exact Test, [K] Kruskal Wallis [C] Chi-Square

Row subscripts denote significant group differences after Bonferroni adjustment ($p \leq 0.05$)

Results: mTBI Group Differences

- Compared to other groups, participants with **BR mTBI** were more likely to:
  - be Male: BR= 92.8% vs NBR= 82.4% vs no mTBI = 77.8%
  - have greater combat exposure: DRRI-2-D median scores: BR=48.0 vs NBR=29.5 vs no mTBI=28.0
  - **be exposed to more controlled detonations: median of BR=15.0 vs NBR=3.0 vs no mTBI= 3.0**
  - be exposed to uncontrolled detonations: median of BR=2.0 vs NBR=1.0 vs no mTBI=1.0

Table 2. Diagnosis, by mTBI Group

	No mTBI (N=72)	NBR mTBI (N=193)	BR mTBI (N=207)
Headache[C,1]	24 (33.3%)[a]	93 (48.2%)[a]	144 (69.6%)[b]
Lower Back Pain[C,1]	42 (58.3%)	119 (61.7%)	143 (69.1%)
PTSD[C,1]	32 (44.4%)[a]	118 (61.1%)[b]	176 (85.0%)[c]
Depression[C,1]	36 (50.0%)	104 (53.9%)	121 (58.5%)
Anxiety[C,1]	42 (58.3%)[a]	138 (71.5%)[a]	179 (86.5%)[b]
Bipolar Disorder[F,1]	2 (2.8%)	10 (5.2%)	10 (4.8 %)
Psychoses[F,1]	0 (0.0%)	5 (2.6%)	4 (1.9%)
Alcohol Dependence and Abuse [F,1]	8 (11.1%)	34 (17.6%)	44 (21.3%)
Substance Abuse, excluding alcohol[C,1]	2 (2.8%)	14 (7.3%)	25 (12.1%)
Nicotine Dependence[F,1]	11 (15.3%)[ab]	34 (17.6%)[a]	60 (29.0%)[b]

[F] Fisher Exact Test, [K] Kruskal Wallis [C] Chi-Square

Row subscripts denote significant group differences after Bonferroni adjustment ($p \leq 0.05$)

Results: Diagnoses

- Compared to other groups, participants with **BR mTBI** were more likely to have higher prevalence of:
  - Headache: **BR=69.6%** vs NBR=48.2% vs no mTBI=33.3%
  - PTSD: **BR=85.0%** vs NBR=61.1% vs no mTBI= **44.4%**
  - Anxiety: **BR=86.5%** vs NBR=71.5% vs no mTBI=58.3%
  - Nicotine Dependence: **BR=29.0%** vs NBR **17.6%** vs. no mTBI=15.3%

- Those with BR mTBI history had a higher prevalence of:
  - headache than Veterans with NBR mTBI or no mTBI,
  - PTSD than Veterans with no mTBI
  - Anxiety than Veterans with NBR mTBI or no mTBI
  - Nicotine Dependence than Veterans with NBR mTBI

Poll Question

Which VA outpatient clinic will have the largest difference in utilization and cost between the mTBI groups?

- Polytrauma/TBI
- Neurology
- Mental Health
- Rehabilitation
- Imaging

Table 3. Outpatient Utilization, by mTBI Group

Category of Care[1,2]	No mTBI (N=72)	NBR mTBI (N=193)	BR mTBI (N=207)
Total Appointments[P]	16.62 (16.21, 17.04)	20.43 (20.15, 20.71)	26.31 (26.01, 26.61)
Primary Care[P]	2.54 (2.38, 2.71)	3.34 (3.22, 3.45)	3.43 (3.33, 3.54)
Mental Health[N]	**3.76 (2.78, 5.07)**	**4.88 (4.06, 5.87)**	**7.10 (5.97, 8.44)**
Polytrauma/TBI[N]	0.30 (0.20, 0.46)	1.13 (0.88, 1.44)	2.85 (2.27, 3.57)
Other Rehabilitation[N]	0.68 (0.46, 1.00)	1.18 (0.94, 1.49)	1.50 (1.21, 1.86)
Specialty Care[N]	2.16 (1.68, 2.77)	2.40 (2.06, 2.79)	2.68 (2.33, 3.10)
Neurology[N]	0.07 (0.04, 0.15)	0.09 (0.06, 0.14)	0.14 (0.10, 0.20)
Orthopedics[N]	0.13 (0.08, 0.23)	0.19 (0.14, 0.27)	0.23 (0.17, 0.31)
Pain [N]	0.04 (0.01, 0.09)	0.11 (0.07, 0.18)	0.19 (0.12, 0.29)
Audiology[N]	0.17 (0.11, 0.24)	0.15 (0.12, 0.18)	0.25 (0.21, 0.30)
Diagnostic[P]	4.40 (4.18, 4.62)	4.42 (4.30, 4.56)	4.11 (4.00, 4.23)
Imaging[N]	0.25 (0.18, 0.34)	0.28 (0.23, 0.33)	0.33 (0.28, 0.39)
Emergency or Urgent Care[N]	0.35 (0.24, 0.50)	0.52 (0.42, 0.63)	0.46 (0.38, 0.56)
Other[N]	0.56 (0.41, 0.77)	0.63 (0.52, 0.76)	0.95 (0.80, 1.13)

P=Poisson, N=Negative Binomial Regression

[1]Only includes primary clinic stops codes (counts do not include secondary clinic stops). A visit is defined as receiving services from a health care provider (i.e., may have one visit to a clinic stop but received services from multiple providers). [2] No Home Care clinic stops codes were reported.

Results: Utilization

- Adjusted overall annual utilization
  - BR mTBI: 26.31 visits, 95% CI 26.01:26.61
  - NBR mTBI: 20.43 visits, 95% CI 20.15:20.71
  - No mTBI: 16.62 visits, 95% CI 16.21:17.04

- Similar pattern of utilization for: primary care, mental health, polytrauma/TBI, other rehabilitation clinics, audiology, neurology, orthopedics, pain clinic, imaging, specialty care, and non-classified visits

- Greatest differences
  - Mental Health: BR=7.10 vs NBR=4.88 vs no mTBI=3.76
  - Polytrauma/TBI: BR=2.85 vs NBR=1.13 vs no mTBI=0.30

- NBR mTBI had the highest diagnostic and urgent/emergency care.

Table 4. Annual VHA Per Patient Outpatient Costs by Clinical Service and mTBI Group

Category of Care[1,2]	No mTBI (N=72)	NBR mTBI (N=193)	BR mTBI (N=207)
Total Appointments[P]	4069.92 (3404.87, 4864.87)	4901.31 (4392.74, 5468.75)	6480.10 (5842.57, 7187.19)
Primary Care[P]	645.52 (548.12, 760.23)	831.76 (758.09, 912.59)	778.89 (713.11, 850.73)
Mental Health[N]	**1085.54 (815.11, 1445.69)**	**1340.92 (1136.67, 1581.86)**	**2001.48 (1733.32, 2311.12)**
Polytrauma/TBI[N]	75.79 (46.33, 123.96)	224.75 (175.00, 288.64)	630.83 (516.06, 771.13)
Other Rehabilitation[N]	149.19 (92.40, 240.87)	128.01 (95.79, 171.08)	201.97 (155.63, 262.11)
Specialty Care[N]	995.65 (754.93, 1313.13)	1086.89 (922.69, 1280.30)	1132.87 (973.32, 1318.57)
Neurology[N]	34.67 (15.29, 78.61)	40.90 (25.89, 64.61)	73.21 (50.57, 105.98)
Orthopedics[N]	33.50 (17.54, 63.98)	41.24 (28.71, 59.24)	64.13 (47.53, 86.51)
Pain [N]	1.84 (0.34, 9.86)	59.36 (31.20, 112.95)	98.97 (54.54, 179.57)
Audiology[N]	72.69 (50.07, 105.53)	63.84 (50.67, 80.44)	106.23 (88.67, 127.27)
Diagnostic[P]	418.02 (347.10, 503.43)	482.44 (432.96, 537.57)	478.84 (432.80, 529.77)
Imaging[N]	114.05 (80.09, 162.41)	143.13 (117.98, 173.64)	172.48 (145.52, 204.44)
Emergency or Urgent Care[N]	136.27 (91.71, 202.47)	234.57 (192.01, 286.56)	189.09 (155.09, 230.55)
Other[N]	20.85 (13.44, 32.34)	47.94 (38.25, 60.09)	59.64 (48.79, 72.90)

G=Gamma Distribution; T=Tweedie Distribution

[1] VINCI outpatient healthcare utilization data was obtained through 2017, however, VINCI outpatient cost data was obtained through 2016. Only data obtained through 2016 is presented in this table.

[2] No Home Care clinic stops codes were reported.

Results: Annual VHA Outpatient Costs

- Adjusted annual 2018 outpatient costs
  - BR mTBI: $6,480, 95%, CI $5,842:$7,187
  - NBR mTBI: $4,901, 95% CI $4,392:$5,468
  - no mTBI: $4,069, 95% CI $3,404:$4,864

- Similar pattern of costs for: mental health, polytrauma/TBI, other rehabilitation clinics, neurology, orthopedics, pain clinic, specialty care, and non-classified visits

- Greatest differences
  - Mental Health: BR=$2,001 vs NBR=$1,340 vs no mTBI=$1,085
  - Polytrauma/TBI: BR=$630 vs NBR=$224 vs no mTBI=$75

- NBR mTBI had the highest costs for primary, urgent/ emergency, and diagnostic care.

Discussion: Military-related Exposures

- Those with BR mTBI were more likely to have greater exposure to: combat, controlled & uncontrolled detonations
  - May be important risk factors for mTBI (especially BR mTBI) and subsequent mental health conditions in Veterans

- The difference in median number of controlled detonation exposures between those with BR and NBR mTBI (15.0 vs 3.0, respectively) was large and deserves further study.

Discussion: Diagnoses

- Veterans with BR mTBI generally had a higher prevalence of headache, PTSD, anxiety, and nicotine dependence relative to the other groups.

- These findings suggest veterans with BR mTBI differ from those with NBR mTBI and may benefit from an interdisciplinary clinical team.

- An evidence synthesis of studies published between 2000 and 2014, which examined health conditions among Veterans with BR vs. NBR PTSD, had inconclusive results for PTSD and Headache. (Greer et al. 2016)[21] The current study provides an important contribution to the literature.

Discussion: Outpatient Utilization

- BR mTBI group had an average of 26 visits/year over 14 years, a large number of services over a long duration of time
  - Mental Health and Polytrauma/TBI clinics highly utilized
- Reasons for differences?
  - BR mTBI associated with injury to more bodily systems (i.e. polytrauma) vs. NBR mTBI?
  - NBR mTBI fewer clinical needs?
  - Lower access to VHA care (i.e. provider perceptions that physical conditions more localized in Veterans with NBR mTBI relative to BR mTBI)?
- VA leadership needs to ensure adequate access to and resources for needed services

Discussion: Cost

- Large difference in annual cost between BR mTBI and no TBI, especially for Mental Health (~$1000).
  - As with utilization, this suggests that BR mTBI requires more Mental Health financial resources
- Primary care utilization is higher among BR mTBI, but Primary Care cost is higher for NBR mTBI veterans.
  - NBR mTBI veterans are using more expensive Primary Care resources than BR mTBI Veterans
  - NBR mTBI Veterans may be using Primary Care, Emergency/Urgent Care, and Diagnostic services to address mental health and polytrauma/TBI health needs.
- Reasons for these differences require further exploration, and may inform planning for staffing and other resources for VHA services, especially mental health, for Veterans with mTBI.

Limitations

- Diagnoses via VHA administrative data ICD codes - not verified with structured clinical interviews.
- Outpatients visits and costs may not be directly associated with mTBI exposure: study did not subset the healthcare utilization data to only occur after a participant's initial mTBI exposure.
- Non-VHA care not included
- Excluded moderate/severe TBI
- Study is descriptive; future studies to use multivariable modeling to account for combat exposure and other confounding variables

Strengths

- Rigorous and standardized method for categorizing mTBI
- 14-year longitudinal data capture of VHA utilization, diagnoses, and costs
- Delineated controlled and uncontrolled detonation exposure in unadjusted analyses.
- Combined data from prospective CENC study with VA administrative diagnosis, utilization, and cost data
  - Creates unique dataset
  - Includes history of combat, training, and lifetime mTBIs.
  - Can provide valuable information to both VA and DoD for planning and policy.

Future Directions

- Veterans with BR mTBI vs. and NBR mTBI, examine:
  - Process of care and clinical outcomes
  - Use and cost of non-VA care
- Study the relationship between:
  - combat/training exposures
    and
  - clinical outcomes, diagnoses, VA utilization, and cost
- Improve coordination and feedback with DoD and the Military Health System
  - Feedback to DoD on exposures within its control (e.g., controlled detonations) may facilitate ways to lessen or prevent its long-term effects

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