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Economic impact of OHCA in the U.S.

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Abstract

Objective: To estimate the annual and lifetime economic productivity loss due to adult out-of-hospital cardiac arrest (OHCA) in the United States (U.S.).

Methods: All adult (age≥ 18 years) non-traumatic EMS-treated OHCA with complete data for age, sex, race, and survival outcomes from the CARES database for 2013-2018 were included. Annual and lifetime labor productivity values, based on age and gender, were obtained from previously published national economic data. Productivity losses for OHCA events were calculated by year in U.S. dollars. Productivity losses for survivors were assigned by cerebral performance category score (CPC): CPC 1 and 2 = 0% productivity loss; CPC 3-5 = 100% productivity loss. Sensitivity analyses were performed assigning CPC 2 varying productivity losses (0-100%) based on CPC score and discharge location. Lifetime productivity values assumed 1% annual growth and 3% discount rate and were adjusted for inflation based on 2016 values. Results were extrapolated to annual U.S. population estimates for the study period.

Results: A total of 338,492 (96.5%) cases met inclusion criteria. The mean annual and lifetime productivity losses per OHCA in 2018 were $48,224 and $638,947 respectively. The total annual economic productivity loss due to OHCA in the U.S. increased from $7.4B in 2013 to $11.3B in 2018. Lifetime economic productivity loss increased from $95.2B in 2013 to $150.2B in 2018. Sensitivity analyses yielded similar findings. Per annual death, OHCA ranked third ($10.2B) in annual economic productivity loss in the U.S. behind cancer ($22.9B) and heart disease ($20.3B) in 2018.

Conclusion: Adult non-traumatic OHCA events are associated with significant annual and lifetime economic productivity losses and should be the focus of public health resources to improve preventative measures and survival outcomes.

Key words: out-of-hospital cardiac arrest, economic impact, economic productivity loss

Introduction

Sudden cardiac arrest (SCA) is responsible for a significant public health burden and is a leading cause of death and disability in the United States (U.S.).[1, 2] There are an estimated 350,000 out-of-hospital cardiac arrests (OHCA) each year in the U.S.[3] The overall survival rate for those who receive treatment is approximately 11%, and neurologic disability is common among survivors.[3] Although our understanding of the public health impact of SCA continues to improve, limited data exists on the societal impact of SCA including non-healthcare related economic losses.
Human capital valuation methods were created by economists in the 1960s to estimate economic productivity.[4, 5] Such methods, which include both market (personal labor earnings) and non-market (household services, caring for others, volunteer services etc.) productivity, are frequently used in cost-of-illness analyses to estimate and compare the non-healthcare related economic impact of a disease.[6] The economic impact of OHCA in the U.S. is poorly understood and has not been evaluated using a national sample of OHCA patients.

To fill this knowledge gap, we estimated the annual and lifetime labor productivity losses due to adult out-of-hospital cardiac arrest in the U.S. from 2013-2018. We hypothesized that OHCA would represent a top 10 leading cause of economic productivity loss in the U.S. Our goal was to help inform researchers, public health officials, and research funding agencies of the social and economic impact of OHCA.

Methods

Study Aim, Design, and Population

The primary aim was to estimate the annual and lifetime economic productivity loss due to adult OHCA in the U.S. The secondary aim was to compare OHCA to other leading causes of death in the U.S. To do so, we performed a retrospective analysis of all adult non-traumatic emergency medical services (EMS)-treated OHCA from the national Cardiac Arrest Registry to Enhance Survival (CARES) database from 2013 to 2018. The Baystate Health Institutional Review Board determined the analysis to be “not human subjects research.”

Inclusion criteria for this evaluation included all adult (age ≥ 18 years) non-traumatic EMS-treated OHCA in the CARES dataset for 2013 to 2018. The CARES database does not capture data on cases where resuscitative efforts are not attempted, thus only EMS-treated OHCA were available for analysis. Excluded from this analysis were pediatric cases (age < 18
years), centenarian cases (age >100), and records with missing data for age, gender, race, mortality disposition, or cerebral performance category (CPC) scores.

Cardiac Arrest Registry to Enhance Survival

The CARES database was developed in 2004 as a collaborative effort between Emory University and the Centers for Disease Control and Prevention to serve as a central repository for cardiac arrest data from EMS systems throughout the U.S.[7] The registry utilizes the Utstein style of OHCA reporting and includes variables from prehospital care through hospital discharge.[8] The program currently includes 28 state-based registries and the District of Columbia with community sites in 14 additional states. CARES represents a catchment area of more than 150 million people or approximately 46% of the U.S. population, with more than 2000 EMS agencies, and 2,500 participating hospitals. The estimated CARES population coverage increased substantially from 61,437,258 in 2013 to 110,133,373 in 2018. Further details of CARES development, design, and data elements have been previously published.[7]

Annual and Lifetime Economic Productivity Loss

Annual and lifetime economic productivity values based on age and gender for the U.S. population were extracted from recently published actuarial data by Grosse et al.[6] The values were derived using the gross human capital approach for economic productivity which included both market (personal labor earnings) and non-market (household services, caring for others, volunteer services etc.) productivity.[6] Lifetime productivity values assumed 1% annual growth and a 3% discount rate. These values were assumed to represent estimated annual and lifetime economic productivity had no OHCA occurred. The differences between estimated economic productivity for the patients with OHCA in CARES and these values represented the productivity loss.
Productivity losses based on age category and gender for all OHCA deaths were tallied by year. Survivors were assigned productivity losses based on neurologic outcome proxied by CPC score at the time of hospital discharge since outcomes beyond hospital discharge are not captured in the CARES dataset. For the primary analysis, an optimistic survivorship scenario was assumed which assigned 0% productivity loss for all survivors with CPC 1 or 2, and 100% productivity loss for all survivors with CPC 3-5. Six sensitivity analyses were performed to determine the impact of different survivorship scenarios on productivity losses. In brief, different reductions in annual and lifetime productivity were derived based on CPC score, and/or discharge location. In some sensitivity analyses, we assumed a reduction in long-term survival using discharge location based on the results of Andrew et al.[9] An additional sensitivity analysis imputed Charlson Comorbidity Index values to the survivors based on the frequencies observed in OHCA patients in Hirlekar et al.[10] and used these values along with known CPC scores and discharge location to create additional survivorship scenarios. More details of the survivorship scenarios used are located in Table 1.

Annual U.S. population estimates for 2013 to 2018 were used to extrapolate the results to a national level.[11] Data were adjusted to inflation based on 2016 values (Supplemental Table 1).[12] The Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (WONDER) database was used to compare OHCA to other leading causes of death in the U.S. for 2018.[13]

Data Availability

Aggregate data from the CARES database is available to researchers to replicate the findings of this study upon approval by the CARES data sharing committee. Further details regarding the CARES data sharing policy are available online.[14]
Results

A total of 350,722 OHCA records were available in the CARES database for the study period. A total of 9,556 (2.7%) pediatric cases (age < 18), 640 (0.2%) centenarian cases (age >100) and 2,171 (0.6%) adult cases with missing data were excluded, resulting in a final sample size of 338,492 (96.5%) records with complete data (Table 2). Overall survival with good neurologic outcome (CPC 1 or 2) remained stable over the study period (8.5% in 2013 to 8.2% in 2018) with a small fraction surviving with CPC = 3 or 4. Overall, 89.6% of the OHCA events resulted in death, though death may have occurred in the field, emergency department, or hospital.

For the study population, the mean annual economic productivity loss per OHCA increased slightly from $44,082 in 2013 to $48,224 in 2018 (Table 3). The mean lifetime productively loss per OHCA increased from approximately $567K in 2013 to $639K in 2018. The productivity loss for younger patient’s varied more as they were more likely to be survivors with varying CPC Scores and discharge locations (Supplemental Figure 1). By a priori definition, the women tended to have lower productivity loss values. The total annual economic productivity loss increased from $1.4B in 2013 to $3.8B in 2018. The total lifetime economic productivity loss increased from $18.5B in 2013 to $50.6B in 2018 (Table 3).

For the U.S. population, the total annual economic productivity loss increased from $7.4B in 2013 to $11.3B in 2018 (FIGURE 1A). The total lifetime economic productivity loss increased from $95.2B in 2013 to $150.2B in 2018 (FIGURE 1B). All six sensitivity analyses yielded consistent findings (FIGURE 2, Supplemental Table 2). Per annual death, OHCA ranked third ($10.2B) in annual economic productivity loss in the U.S. behind cancer ($22.9B) and heart disease ($20.3B) in 2018 (FIGURE 3).
Discussion

In this evaluation of nearly 340,000 records from the CARES database, adult non-traumatic EMS-treated OHCA was found to be the third leading cause of economic productivity loss in 2018 when compared to the leading causes of death in the U.S. The economic productivity loss due to OHCA was found to significantly increase over time despite the mean annual productivity loss per OHCA remaining relatively stable, ranging from $44K to $48K over the study period. This increase does not appear to be due to OHCA becoming more common or deadly, but instead due to improved national cardiac arrest surveillance over time leading to a more accurate estimate. The CARES population catchment increased from 61.4 million to 110.1 million from 2013 to 2018. The ratio of cases per population catchment within CARES increased by 34% (from 0.00056 to 0.00073) which suggests that the overall burden of OHCA is considerably higher than previous estimates.

Resuscitation science traditionally relies on metrics such as overall incidence, number of deaths, short-term neurologic outcomes, or disability-adjusted life years to estimate the public health impact of SCA.[3, 15-17] Limited data exists on the societal and non-healthcare related economic impact of SCA. Mirzaei et al. recently estimated the lifetime economic loss due to SCA in the U.S. to be ~$51B in 2014.[18] Their data was limited to adult SCA deaths, aged 20-64 years, from a single county in North Carolina. We found the lifetime economic loss for all adult OHCA, aged 18-99 years, to be significantly larger, approximately $108B in 2014. The discrepancy in our findings are due to a number of factors including: (1) our analysis estimated productivity losses for both OHCA survivors and those who died, (2) our analysis captured a broader age range (18 to 99 years vs. 20 to 64 years, with 51.1% of our population age 65 or older), (3) our analysis utilized more recently published labor productivity values compare to the
older values used in their analysis,[19] and (4) the CARES database captures a more robust, accurate, and representative OHCA population compared to data from a single US county.

When comparing our findings to the CDC WONDER mortality data, the annual economic productivity loss due to OHCA deaths in 2018 ($10.2B) was comparable to other leading causes of death in the U.S. such as cancer ($22.9B), heart disease ($20.3B), chronic obstructive pulmonary disease ($4.8B), and stroke ($4B).[13] These findings are consistent with our previous work which noted OHCA compares similarly to the leading causes of disability-adjusted life years in the U.S.[2] Despite the significant burden of disease, SCA receives orders of magnitude less research funding when compared to other leading causes of mortality.[20] Our findings highlight the need for additional research and public health resources to improve outcomes and reduce the societal burden associated with SCA.

Limitations

While our study’s sample size, novel findings, and econometric approach are strengths, our study does have limitations. Participation in CARES is voluntary and our estimates were based on records from the national CARES database, which covered approximately 46% of the U.S. population in 2018. Consequently, our results may be less generalizable to patient populations that are underrepresented or outside of the CARES database including rural areas and locations with low socioeconomic status. Our findings underestimate the total economic productivity loss for SCA as a whole, as we do not include estimates for pediatrics, traumatic cardiac arrest, in-hospital cardiac arrest, or individuals experiencing OHCA where no resuscitative efforts were attempted. Given that pediatrics would represent a larger portion of economic loss (more potential life years lost), and half of OHCA do not undergo attempted resuscitation, our estimate is conservative.
A limitation of our methodology is that the sensitivity estimates for survivors were based on CPC score at the time of hospital discharge and discharge location. The primary analysis assumed all patients with CPC 1 or 2 would achieve full economic productivity and we attempted to vary this “optimistic” assumption among these survivors. Patient comorbidities are lacking as these data are optional fields within CARES with limited data available. To address this, we did impute Charlson Comorbidity Indices based on empirical results from Hirlekar et al[10] as way to further refine the estimated productivity of the surviving patients. All six sensitivity analyses found similar productivity losses to the primary analysis. This is due to the very high mortality rate and premature death associated with OHCA, which constitutes the vast majority of the economic burden due to OHCA. The stability of the annual productively loss per OHCA values in the primary and sensitivity analyses is notable and is a consequence of having over 90% of the patients dying or with a CPC score $\leq 3$. In fact, if we were to assume all patients (survivors and non-survivors) had a total productivity loss for their OHCA event, then the annual productivity loss would be approximately $5K higher than the primary analysis (Supplemental Table 3). Other limitations are that analysis does not account for changes in CPC score beyond hospital discharge. Finally, these results are subject to the same limitations found in the annual and lifetime productivity estimates by Grosse et al.[6]

**Conclusion**

Adult non-traumatic OHCA is a leading cause of economic productivity loss in the United States and should be a focus of public health policy and resources to improve preventative measures and survival outcomes. Moreover, our methodology shows that total lifetime productivity loss estimates for OHCA increased over time due to improvements in national cardiac arrest surveillance. A significant economic burden is associated with OHCA and these
findings should help inform policy makers, funding agencies, and the public of the societal impact of OHCA in the U.S.

Author Contributions

RAC designed the study, analyzed the data, and wrote the manuscript. BHN performed the statistical analysis, assisted with study design, and participated in manuscript writing. MCK, SD, and TJM participated in manuscript writing and editing. BM assisted with study design and edited the manuscript. All authors have read and approved of the manuscript.

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CARES participating sites can be located at: https://mycares.net/sitepages/map.jsp

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None.

Disclosures

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Figures

Figure 2. Sensitivity analysis of annual productivity loss due to out-of-hospital cardiac arrest in the United States with varying losses based on cerebral performance category score, Charlson Comorbidity Index, and survivor discharge location.
Figure 3. Annual economic productivity loss due to the leading causes of death in the U.S. in 2018.
Supplemental Figure 1: Lifetime economic productivity loss stratified by age and gender for 2016.
Table 1. Sensitivity analyses performed with varying productivity losses assigned based on cerebral performance category score and discharge location.

<table>
<thead>
<tr>
<th>Sensitivity analysis</th>
<th>Discharge Location</th>
<th>CPC 1 Productivity Loss</th>
<th>CPC 2 Productivity Loss</th>
<th>CPC 3-5 Productivity Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary analysis</td>
<td>Home</td>
<td>0%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>12%</td>
<td>16%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>SNF</td>
<td>36%</td>
<td>39%</td>
<td>100%</td>
</tr>
<tr>
<td>Sensitivity analysis #1</td>
<td>Home</td>
<td>0%</td>
<td>5%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>12%</td>
<td>16%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>SNF</td>
<td>36%</td>
<td>39%</td>
<td>100%</td>
</tr>
<tr>
<td>Sensitivity analysis #2</td>
<td>Home</td>
<td>15%</td>
<td>25%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>25%</td>
<td>34%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>SNF</td>
<td>45%</td>
<td>52%</td>
<td>100%</td>
</tr>
<tr>
<td>Sensitivity analysis #3</td>
<td>Home</td>
<td>CCI 0-2; 10%</td>
<td>CCI 0-2; 30%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCI 3-4; 15%</td>
<td>CCI 3-4; 35%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCI 5-6; 30%</td>
<td>CCI 5-6; 50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCI 7+; 45%</td>
<td>CCI 7+; 65%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>CCI 0-2; 20%</td>
<td>CCI 0-2; 40%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCI 3-4; 30%</td>
<td>CCI 3-4; 50%</td>
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<td>CCI 5-6; 40%</td>
<td>CCI 5-6; 60%</td>
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<td></td>
<td>CCI 7+; 65%</td>
<td>CCI 7+; 85%</td>
<td></td>
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<tr>
<td></td>
<td>SNF</td>
<td>CCI 0-2; 40%</td>
<td>CCI 0-2; 60%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCI 3-4; 45%</td>
<td>CCI 3-4; 65%</td>
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<td>CCI 5-6; 50%</td>
<td>CCI 5-6; 70%</td>
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<tr>
<td></td>
<td></td>
<td>CCI 7+; 85%</td>
<td>CCI 7+; 100%</td>
<td></td>
</tr>
</tbody>
</table>

Note: CPC = cerebral performance category score. SNF = skilled nursing facility. CCI = Charlson Comorbidity Index.
Table 2. Exclusion criteria and derivation of study population.

<table>
<thead>
<tr>
<th>Exclusion Criteria</th>
<th>Total Number with this exclusion criterion (not including prior criteria and not mutually exclusive)</th>
<th>N = 350,722; The initial sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missing Gender</td>
<td>19</td>
<td>350,703</td>
</tr>
<tr>
<td>Missing Age</td>
<td>228</td>
<td>350,477</td>
</tr>
<tr>
<td>Missing Race</td>
<td>116</td>
<td>350,368</td>
</tr>
<tr>
<td>Age &lt; 18</td>
<td>9,556</td>
<td>340,820</td>
</tr>
<tr>
<td>Age 100 or older (productivity data are set to 0 or missing for these patients)</td>
<td>640</td>
<td>340,180</td>
</tr>
<tr>
<td>Missing Hospital Outcome</td>
<td>1,061</td>
<td>339,215</td>
</tr>
<tr>
<td>Missing CPC Score for Survivors</td>
<td>747</td>
<td>Final Sample Size = 338,492</td>
</tr>
</tbody>
</table>
Table 3. Annual and lifetime economic productivity loss due to adult OHCA in the U.S. from 2013 to 2018.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases, n</td>
<td>32,657</td>
<td>42,160</td>
<td>49,940</td>
<td>61,560</td>
<td>73,049</td>
<td>79,126</td>
</tr>
<tr>
<td>Mean annual productivity loss per OHCA</td>
<td>$44,082</td>
<td>$44,651</td>
<td>$44,969</td>
<td>$45,840</td>
<td>$47,044</td>
<td>$48,224</td>
</tr>
<tr>
<td>Mean lifetime productivity loss per OHCA</td>
<td>$566,909</td>
<td>$577,486</td>
<td>$586,431</td>
<td>$609,477</td>
<td>$631,473</td>
<td>$638,947</td>
</tr>
<tr>
<td>Total annual productivity loss</td>
<td>$1,439,573,623</td>
<td>$1,882,504,427</td>
<td>$2,245,272,821</td>
<td>$2,821,888,841</td>
<td>$3,436,551,974</td>
<td>$3,815,759,222</td>
</tr>
<tr>
<td>Total lifetime productivity loss</td>
<td>$18,513,540,180</td>
<td>$24,346,878,639</td>
<td>$29,236,428,730</td>
<td>$37,457,827,557</td>
<td>$48,128,475,522</td>
<td>$50,557,345,502</td>
</tr>
<tr>
<td>US Population</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cases*, n</td>
<td>168,001</td>
<td>187,769</td>
<td>208,618</td>
<td>224,286</td>
<td>231,427</td>
<td>235,055</td>
</tr>
<tr>
<td>Total annual productivity loss</td>
<td>$7,405,803,156</td>
<td>$8,384,067,526</td>
<td>$9,379,235,545</td>
<td>$10,281,272,839</td>
<td>$10,887,257,892</td>
<td>$11,335,314,369</td>
</tr>
<tr>
<td>Total lifetime productivity loss</td>
<td>$95,241,061,228</td>
<td>$108,434,265,470</td>
<td>$122,131,169,390</td>
<td>$136,472,906,919</td>
<td>$146,139,983,907</td>
<td>$150,187,979,225</td>
</tr>
</tbody>
</table>

Note: $USD; OHCA = out-of-hospital cardiac arrest; * = National adult EMS-treated non-traumatic OHCA estimates based on number of annual CARES cases, annual CARES population catchment, and annual US population estimates.

Supplemental Table 1. Inflation adjustment factors of present worth from 2016.

Supplemental Table 2. Results of sensitivity analyses with varying productivity losses assigned based on cerebral performance category score, discharge location, and Charlson comorbidity index.

Supplemental Table 3. Primary analysis productivity loss vs. Worst-case scenario.

References

Economic impact of OHCA in the U.S.


Author Credit Statement

RAC designed the study, analyzed the data, and wrote the manuscript. BHN performed the statistical analysis, assisted with study design, and participated in manuscript writing. MCK, SD, and TJM participated in manuscript writing and editing. BM assisted
with study design and edited the manuscript. All authors have read and approved of the manuscript.

Conflict of Interest Statement
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