**Supplemental Figures and Tables**

Supplemental Figure 1. Study Inclusion Flow Chart



In the first step, we limited to those individuals who had both cancer and were enrolled in Medicare who were 66 years old or older (-100,696), those were on fee-for-service (FFS), to ensure claims completeness (-149,771), those who had at least one valid Medicare claim (-1,446), and those with either breast, colon, lung, or prostate cancer as the primary site on their first cancer record (-36,052). Finally, we removed in situ cases (-8,057), and for supplementary analyses excluded those who were diagnosed in 2016 (-5,803) and those who had a missing multimorbidity weighted index (MWI) (4,590).

Prior to this inclusion criteria, the investigators undertook a process to link Medicare claims with cancer registry data. From an initial 526,572 records in the Ohio Cancer Incidence Surveillance System (OCISS) Finder File which included patients with cancer of all ages (the live version which had not been cleaned yet), there were 35,927 duplicate rows, 44,881 duplicate Social Security numbers (SSNs), and 8,871 invalid SSNs. This resulted in 482,182 eligible (of all ages) to be matched, of whom 344,936 were matched. However, after receiving the cleaned and verified version of the Finder File we were able to successfully match 325,162 unique Medicare Beneficiaries who were part of the OCISS. It was at this point that we applied our additional inclusion criteria.

Supplemental Table 1. Hazard ratio and 95% confidence interval for survival, stratified by cancer type and frailty or multimorbidity measure, **2012-2015a**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Breast** | **Colorectal** | **Lung** | **Prostate** |
|  | **Elixhauser** | | | |
| Age | 1.08 (1.07, 1.09) | 1.05 (1.05, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.07, 1.10) |
| Sex (ref: Male) | - | 0.96 (0.86, 1.08) | 0.91 (0.85, 0.97) | - |
| Stage (ref: Localized) | - | - | - | - |
| Regional | 2.01 (1.71, 2.36) | 1.66 (1.43, 1.93) | 1.99 (1.80, 2.20) | 1.75 (1.30, 2.35) |
| Distant | 8.43 (6.99, 10.17) | 7.43 (6.37, 8.67) | 4.42 (4.03, 4.84) | 6.19 (4.99, 7.67) |
| Unstaged | 4.23 (3.12, 5.75) | 3.89 (3.19, 4.75) | 4.16 (3.57, 4.85) | 1.70 (1.31, 2.20) |
| Elixhauser (ref: 0 comorbidities) | - | - | - | - |
| 1 or 2 Comorbidities | 0.94 (0.69, 1.28) | 1.09 (0.87, 1.36) | 0.92 (0.81, 1.05) | 0.76 (0.58, 1.00) |
| 3 or 4 Comorbidities | 1.28 (0.94, 1.75) | 1.29 (1.03, 1.62) | 0.99 (0.87, 1.13) | 1.08 (0.82, 1.42) |
| 5+ Comorbidities | 2.36 (1.74, 3.19) | 1.96 (1.58, 2.43) | 1.15 (1.01, 1.31) | 1.63 (1.24, 2.15) |
| Harrell's C statistic | 0.78 | 0.74 | 0.69 | 0.80 |
|  | **Claims Frailty Index** | | | |
| Age | 1.07 (1.06, 1.08) | 1.05 (1.04, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.07, 1.10) |
| Sex (ref: Male) | - | 0.90 (0.80, 1.01) | 0.89 (0.84, 0.95) | - |
| Stage (ref: Localized) | - | - | - | - |
| Regional | 1.96 (1.67, 2.30) | 1.68 (1.44, 1.95) | 2.00 (1.80, 2.21) | 1.73 (1.28, 2.32) |
| Distant | 8.22 (6.81, 9.91) | 7.62 (6.53, 8.90) | 4.45 (4.06, 4.88) | 6.00 (4.84, 7.45) |
| Unstaged | 3.59 (2.63, 4.89) | 3.71 (3.04, 4.52) | 4.07 (3.49, 4.75) | 1.70 (1.31, 2.21) |
| CFI (ref: Non-Frail) | - | - | - | - |
| Pre-Frail | 1.68 (1.06, 2.66) | 1.68 (1.24, 2.29) | 1.17 (1.01, 1.37) | 1.71 (1.23, 2.38) |
| Mildly Frail | 3.15 (1.96, 5.05) | 2.54 (1.84, 3.50) | 1.43 (1.22, 1.69) | 2.73 (1.88, 3.97) |
| Moderately or Severely Frail | 6.21 (3.80, 10.16) | 4.75 (3.35, 6.75) | 1.84 (1.52, 2.22) | 3.82 (2.33, 6.25) |
| Harrell's C statistic | 0.78 | 0.75 | 0.69 | 0.80 |
| Note: a Analyses restricted to a consistent sample of only those patients who were diagnosed in 2015 or earlier, given that as the Multimorbidity-Weighted Index (MWI) has only been published for ICD-9 data. | | | | |

Supplemental Table 2. Partial likelihood ratio tests for Cox Proportional Hazard Models presented in Supplemental Table 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Partial LRTa, Alternative Hypothesis** | **Breast** | **Colorectal** | **Lung** | **Prostate** |
| Elixhauser fits better than MWI | 0.574 | 0.254 | 0.866 | 0.023 |
| MWI fits better than Elixhauser | 0.426 | 0.746 | 0.134 | 0.977 |
| Elixhauser fits better than CFI | 0.974 | 0.993 | 1 | 0.498 |
| CFI fits better than Elixhauser | 0.026 | 0.007 | 0.0002 | 0.502 |
| MWI fits better than CFI | 0.978 | 1 | 1 | 0.972 |
| CFI fits better than MWI | 0.022 | 0.0005 | 0.001 | 0.028 |
| Note: a see *plrtest*: <https://rdrr.io/github/thomashielscher/nonnestcox/man/plrtest.html> | | | | |

Abbreviations: MWI, Multimorbidity-Weighted Index; CFI, Claims Frailty Index

To compare Elixhauser-MWI, Elixhauser-CFI, and CFI-MWI within each cancer type using the partial likelihood ratio test (LRT), we tested two sets of hypotheses to determine which model was best in the pairwise comparisons and observed the below p-values. Overall, these tests are consistent this those in the main manuscript using Harrell’s C statistic that the CFI model perhaps performs the best.

Supplemental Table 3. C-statistics and Harrell’s C using continuous measures of multiple chronic conditions and frailty, **2012-2015**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Breast** | **Colon** | **Lung** | **Prostate** |
|  | **Elixhauser** | | | |
| Age | 1.08 (1.07, 1.09) | 1.05 (1.04, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.08, 1.10) |
| Sex (ref: Male) | - | 0.95 (0.85, 1.07) | 0.91 (0.85, 0.97) | - |
| *Stage (ref: Localized)* | - | - | - | - |
| Distant | 8.64 (7.16, 10.42) | 7.45 (6.38, 8.69) | 4.44 (4.05, 4.87) | 6.07 (4.90, 7.53) |
| NA/Unstaged | 4.10 (3.01, 5.56) | 3.84 (3.15, 4.69) | 4.10 (3.52, 4.78) | 1.71 (1.32, 2.22) |
| Regional | 2.00 (1.71, 2.35) | 1.66 (1.43, 1.93) | 1.99 (1.80, 2.21) | 1.75 (1.30, 2.35) |
| Elixhauser comorbidities | 1.17 (1.15, 1.20) | 1.10 (1.08, 1.11) | 1.04 (1.03, 1.05) | 1.11 (1.08, 1.14) |
| Harrell's C statistic | 0.79 | 0.75 | 0.69 | 0.8 |
|  | **Claims Frailty Index** | | | |
| Age | 1.07 (1.06, 1.08) | 1.05 (1.04, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.08, 1.10) |
| Sex (ref: Male) | - | 0.90 (0.81, 1.01) | 0.89 (0.83, 0.95) | - |
| *Stage (ref: Localized)* | - | - | - | - |
| Distant | 8.28 (6.86, 9.99) | 7.85 (6.72, 9.17) | 4.47 (4.08, 4.89) | 6.07 (4.90, 7.53) |
| NA/Unstaged | 3.55 (2.61, 4.83) | 3.74 (3.07, 4.56) | 4.08 (3.50, 4.76) | 1.71 (1.32, 2.22) |
| Regional | 1.96 (1.67, 2.30) | 1.69 (1.45, 1.97) | 2.00 (1.80, 2.21) | 1.75 (1.30, 2.35) |
| CFI | 565.38 (256.44, 1246.52) | 111.57 (55.27, 225.23) | 8.45 (5.57, 12.81) | 1.11 (1.08, 1.14) |
| Harrell's C statistic | 0.79 | 0.75 | 0.7 | 0.8 |
| Note: a Analyses restricted to a consistent sample of only those patients who were diagnosed in 2015 or earlier, given that as the Multimorbidity-Weighted Index has only been published for ICD-9 data. | | | | |

Supplemental Table 4. C-statistics and Harrell’s C using continuous **and standardized** measures of multiple chronic conditions and frailty, **2012-2015. a,b**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Breast** | **Colon** | **Lung** | **Prostate** |
|  | **Elixhauser** | | | |
| Age | 1.08 (1.07, 1.09) | 1.05 (1.04, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.08, 1.10) |
| Sex (ref: Male) | - | 0.95 (0.85, 1.07) | 0.91 (0.85, 0.97) | - |
| *Stage (ref: Localized)* | - | - | - | - |
| Distant | 8.64 (7.16, 10.42) | 7.45 (6.38, 8.69) | 4.44 (4.05, 4.87) | 6.07 (4.90, 7.53) |
| NA/Unstaged | 4.10 (3.01, 5.56) | 3.84 (3.15, 4.69) | 4.10 (3.52, 4.78) | 1.71 (1.32, 2.22) |
| Regional | 2.00 (1.71, 2.35) | 1.66 (1.43, 1.93) | 1.99 (1.80, 2.21) | 1.75 (1.30, 2.35) |
| Elixhauser comorbidities | 1.51 (1.43, 1.60) | 1.31 (1.25, 1.37) | 1.11 (1.08, 1.15) | 1.26 (1.18, 1.35) |
| Harrell's C statistic | 0.79 | 0.75 | 0.69 | 0.8 |
|  | **Claims Frailty Index** | | | |
| Age | 1.07 (1.06, 1.08) | 1.05 (1.04, 1.06) | 1.03 (1.02, 1.03) | 1.08 (1.07, 1.10) |
| Sex (ref: Male) | - | 0.90 (0.81, 1.01) | 0.89 (0.83, 0.95) | - |
| *Stage (ref: Localized)* | - | - | - | - |
| Distant | 8.28 (6.86, 9.99) | 7.85 (6.72, 9.17) | 4.47 (4.08, 4.89) | 5.89 (4.75, 7.31) |
| NA/Unstaged | 3.55 (2.61, 4.83) | 3.74 (3.07, 4.56) | 4.08 (3.50, 4.76) | 1.74 (1.34, 2.26) |
| Regional | 1.96 (1.67, 2.30) | 1.69 (1.45, 1.97) | 2.00 (1.80, 2.21) | 1.74 (1.29, 2.34) |
| CFI | 1.50 (1.43, 1.58) | 1.38 (1.31, 1.44) | 1.16 (1.13, 1.20) | 1.32 (1.23, 1.41) |
| Harrell's C statistic | 0.79 | 0.75 | 0.7 | 0.8 |
|  | **Multimorbidity Weighted Index** | | | |
| Age | 1.08 (1.07, 1.09) | 1.05 (1.05, 1.06) | 1.03 (1.02, 1.03) | 1.09 (1.08, 1.10) |
| Sex (ref: Male) | - | 0.96 (0.86, 1.07) | 0.91 (0.85, 0.97) | - |
| *Stage (ref: Localized)* | - | - | - | - |
| Distant | 9.03 (7.48, 10.90) | 7.50 (6.42, 8.75) | 4.47 (4.08, 4.90) | 6.22 (5.01, 7.72) |
| NA/Unstaged | 4.28 (3.15, 5.81) | 3.68 (3.02, 4.49) | 4.14 (3.55, 4.82) | 1.73 (1.34, 2.24) |
| Regional | 2.04 (1.74, 2.39) | 1.64 (1.41, 1.91) | 2.00 (1.80, 2.21) | 1.71 (1.27, 2.31) |
| MWI | 1.06 (1.05, 1.07) | 1.04 (1.03, 1.05) | 1.01 (1.01, 1.02) | 1.04 (1.02, 1.05) |
| Harrell's C statistic | 0.78 | 0.74 | 0.69 | 0.8 |
| Notes: a Analyses restricted to a consistent sample of only those patients who were diagnosed in 2015 or earlier, given that as the Multimorbidity-Weighted Index (MWI) has only been published for ICD-9 data.; b Each measure (Elixhauser, Claims Frailty Index, and MWI) was standardized with a mean of 0 and a standard deviation of 1 and then treated as a continuous variable. This allowed for a more direct comparison, although the interpretation is more complex. | | | | |

Supplemental Table 5. Overlap (percent) of the Elixhauser comorbidities, Claims Frailty Index (CFI), and Multimorbidity Weighted Index (MWI), 2012-2016

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Overlap of Elixhauser and CFI, row % | column %** | | | | | | | | | |
|  | **Non-Frail** | | **Pre-Frail** | | **Mildly Frail** | | **Moderately or Severely Frail** | | **Total** |
|  | Row % | Col % | Row % | Col % | Row % | Col % | Row % | Col % |  |
| **0** | 12 | 49 | 88 | 34 | 0 | 0 | 0 | 0 | 8,480 |
| **1 or 2** | 11 | 46 | 86 | 35 | 3 | 6 | 0 | 0 | 8,828 |
| **3 or 4** | 2 | 5 | 80 | 23 | 18 | 27 | 1 | 5 | 6,189 |
| **5+** | 0 | 0 | 34 | 9 | 49 | 67 | 17 | 95 | 5,643 |
| **Total** | 2,047 | | 21,948 | | 4,139 | | 1,006 | |  |
|  |  | |  | |  | |  | |  |
| **Overlap of Elixhauser and MWI Quartiles, row % | column %** | | | | | | | | | |
|  | **Q1** | | **Q2** | | **Q3** | | **Q4** | | **Total** |
|  | Row % | Col % | Row % | Col % | Row % | Col % | Row % | Col % |  |
| **0** | 80 | 37 | 18 | 8 | 2 | 1 | 0 | 0 | 8,480 |
| **1 or 2** | 37 | 56 | 38 | 57 | 22 | 33 | 4 | 5 | 8,828 |
| **3 or 4** | 6 | 7 | 28 | 30 | 42 | 44 | 24 | 25 | 6,189 |
| **5+** | 0 | 0 | 5 | 5 | 23 | 22 | 72 | 69 | 5,643 |
| **Total** | 5,794 | | 5,856 | | 5,803 | | 5,825 | |  |
|  |  | |  | |  | |  | |  |
| **Overlap of CFI and MWI Quartiles, row % | column %** | | | | | | | | | |
|  | **Q1** | | **Q2** | | **Q3** | | **Q4** | | **Total** |
|  | Row % | Col % | Row % | Col % | Row % | Col % | Row % | Col % |  |
| **Non-Frail** | 75 | 26 | 21 | 7 | 4 | 2 | 1 | 0 | 2,040 |
| **Pre-Frail** | 26 | 73 | 32 | 88 | 29 | 80 | 13 | 36 | 16,105 |
| **Mildly Frail** | 1 | 1 | 6 | 5 | 25 | 18 | 67 | 48 | 4,129 |
| **Moderately or Severely Frail** | 0 | 0 | 1 | 0 | 5 | 1 | 94 | 17 | 1,004 |
| **Total** | 5,794 | | 5,856 | | 5,803 | | 5,825 | |  |
| Note: a Values are rounded due to data privacy concerns. | | | | | | | | | |

Supplemental Figure 2. Overlap of Elixhauser comorbidities, Claims Frailty Index (CFI), and Multimorbidity Weighted Index (MWI)



Supplemental Figure 3. Survival curves for the four cancers, stratified by the quartile of Claims Frailty Index.

