Supplementary Methods

From 01st Jan 2007 to 03rd March 2019, there were 2,753,465 episodes from 2,505,488 spells in 750,361 individuals. We first excluded admissions before 01st Jan 2008 (n=200,407), to reduce coding bias. We excluded admissions with missing primary diagnostic codes (n=12,710). We excluded admissions in whom the mortality rate was very low, specifically retaining only ordinary admissions and excluding admissions which were day cases (n=855,243; 19 deaths within 30-days of admission), regular day admissions (n=209,965; 21 deaths), regular night admissions (n=24; 0 deaths), those using mother and baby delivery facilities only (n=0), and those missing this information (n= 2; 0 deaths). This left 1,242,925 episodes from 566,044 individuals. We then also excluded two groups with distinct reasons for hospitalisation, indicated by low comorbidities and low mortality, specifically maternity admissions (admission method code 31 (admitted ante partum) or 32 (admitted post-partum); 144,358 spells; 11 deaths; 95.1% with a Charlson score of 0 calculated using the diagnostic dominant method) and new-born babies (admission method code 82 (the birth of a baby within current health care provider) or 83 (baby born outside of health care provider except when born at home as intended) with an age less than 0.2 years (empirically chosen); 94,002 spells, 681 (0.7%) deaths, 99.98% with a Charlson score of zero). This left 1,004,565 admissions in 454,526 individuals; 13 admissions from 13 individuals with unknown sex were excluded, leaving 1,004,552 admissions from 454,513 individuals for analysis.

Due to the large number of admissions, we included all of the following administrative variables in Cox regression models to adjust for confounding as fully as possible, as previously identified through variable selection in a previous IORD study(1). These were age, sex, ethnicity (White, Black, Asian, Other, Unknown), admission source (usual residence, temporary residence, NHS general ward, other), admission method (elective, emergency, or other), Clinical Classifications Software (CCS) group(2) (35 categories), consultant code (surgery, medical, and other), admission day of week, admission year,

admission day of year, admission hour, any complex admission in last year (defined as admissions with two or more consultant episodes), number of admissions in last year, and number of diagnosis codes. CCS groups containing fewer than 3000 individuals were combined into "other" and CCS groups with <1% mortality were combined into "low risk" to improve model stability and convergence. Admission day of year was modelled using a sin()+cos() function to ensure a smooth transition in risk between years. Natural cubic splines were used for non-linear effects of continuous variables. Pairwise interactions were included based on selection in the previous study; specifically admission hour with admission day of week, number of admissions in previous year with number of complex admissions in the previous year, and age with number of admissions in the last year. For individuals with no vital status checked >30 days after admissions and were not known to have died were censored at discharge date.

Calculating the Lookback_weighted score

For each comorbidity of the Charlson score, the number of occurrences in the last year (including in the diagnostic-dominant episode) were counted and then divided by the total number of admissions in that timeframe. This resulted in a number between 0 (no occurrences of the comorbidity in the prior year) and 1 (comorbidity present in all admissions in the prior year). This was then multiplied by the individual comorbidity weighting e.g. 14 for dementia. This process was repeated for all 17 comorbidities, and then the comorbidity weightings were summed together to produce an overall score. This score was always less than or equal to the lookback_1y method as, for the lookback_1y method, the total weighting of the comorbidity was considered irrespective of the number of times the comorbidity occurred in the prior year.

Supplementary Table 1: Frequency of the conditions constituting the Charlson and the Elixhauser scores in episodes and individuals.

(A) Charlson Comorbidities

Charlson Component	Score weighting	Episodes, n (%)	Individuals, n (%)	Diagnostic-dominant Episodes, n (%)
TOTAL		**2,225,998**	**454,513**	**1,004,552**
Acute myocardial infarction	5	74,791 (3.4)	24,611 (5.4)	43,370 (4.3)
Cerebral vascular disease	11	30,316 (1.4)	14,443 (3.2)	16,876 (1.7)
Congestive heart failure	13	53,980 (2.4)	19,614 (4.3)	30,087 (3.0)
Connective tissue disorder	4	30,253 (1.4)	9,744 (2.1)	17,575 (1.8)
Dementia	14	45,684 (2.1)	15,314 (3.4)	28,482 (2.8)
Diabetes	3	173,001 (7.8)	40,712 (9.0)	95,481 (9.5)
Liver disease	8	11,801 (0.5)	2,986 (0.7)	6,042 (0.6)
Peptic ulcer	9	7,928 (0.4)	4,816 (1.1)	3,418 (0.3)
Peripheral vascular disease	6	33,951 (1.5)	14,619 (3.2)	19,905 (2.0)
Pulmonary disease	4	186,372 (8.4)	60,764 (13.4)	107,102 (10.7)
Cancer	8	63,971 (2.9)	25,486 (5.6)	37,135 (3.7)
Diabetes complications	-1	18,411 (0.8)	5,823 (1.3)	9,199 (0.9)
Paraplegia	1	14,434 (0.7)	5,903 (1.3)	8,179 (0.8)
Renal disease	10	83,180 (3.7)	24,067 (5.3)	42,050 (4.2)

Charlson Component	Score weighting	Episodes, n (%)	Individuals, n (%)	Diagnostic-dominant Episodes, n (%)
Metastatic cancer	14	57,437 (2.6)	16,008 (3.5)	29,903 (3.0)
Severe liver disease	18	5,007 (0.2)	1,898 (0.4)	2,255 (0.2)
HIV	2	1,067 (0.1)	392 (0.1)	536 (0.1)

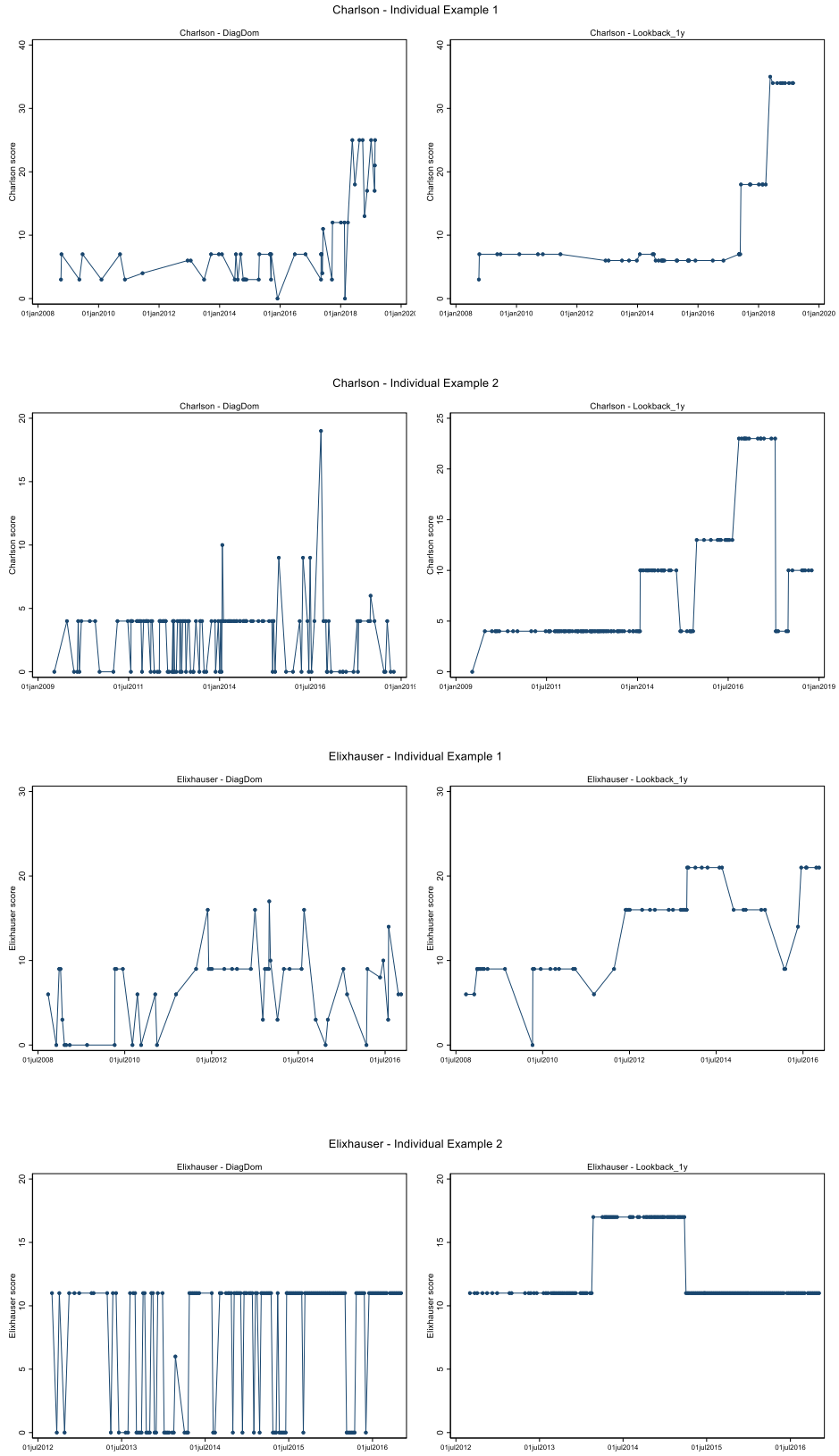
(B) Elixhauser Comorbidities

Elixhauser Component	Score weighting	Episodes, n (%)	Individuals, n (%)	Diagnostic-dominant episodes
TOTAL		**2,225,998**	**454,513**	**1,004,552**
Congestive Heart Failure	7	62,412 (2.8)	21,655 (4.8)	34,603 (3.4)
Cardiac Arrhythmias	5	181,676 (8.2)	58,269 (12.8)	107,308 (10.7)
Valvular Disease	-1	60,854 (2.7)	23,794 (5.3)	33,286 (3.3)
Pulmonary circulation disorders	4	14,400 (0.7)	6,685 (1.5)	7,888 (0.8)
Peripheral Vascular Disorders	2	37,432 (1.7)	15,730 (3.5)	21,785 (2.2)
Hypertension, uncomplicated	0	372,486 (16.7)	117,271 (25.8)	210,419 (21.0)
Paralysis	7	17,074 (0.8)	7,129 (1.6)	9,887 (1.0)
Other Neurological Disorders	6	63,958 (2.9)	21,308 (4.7)	39,232 (3.9)
Chronic Pulmonary Disease	3	186,934 (8.4)	60,865 (13.4)	107,449 (10.7)

Elixhauser Component	Score weighting	Episodes, n (%)	Individuals, n (%)	Diagnostic-dominant episodes
Diabetes, Uncomplicated	0	168,869 (7.6)	40,348 (8.9)	92,936 (9.3)
Diabetes, Complicated	0	21,694 (1.0)	6,794 (1.5)	11,185 (1.1)
Hypothyroidism	0	58,639 (2.6)	20,110 (4.4)	36,127 (3.6)
Renal Failure	5	290,631 (13.1)	24,725 (5.4)	49,448 (4.9)
Liver Disease	11	31,660 (1.4)	10,187 (2.2)	16,609 (1.7)
Peptic Ulcer Disease	0	6,955 (0.3)	4,335 (1.0)	2,998 (0.3)
AIDS/ HIV	0	972 (0.0)	360 (0.1)	500 (0.1)
Lymphoma	9	9,961 (0.5)	2,980 (0.7)	6,373 (0.6)
Metastatic Cancer	12	57,437 (2.6)	16,008 (3.5)	16,008 (3.5)
Solid Tumour w/o metastasis	4	60,701 (2.7)	23,180 (5.1)	37,656 (3.8)
Rheumatoid Arthritis/ Collagen Vascular	0	37,895 (1.7)	12,171 (2.7)	21,455 (2.1)
Coagulopathy	3	10,515 (0.5)	4,914 (1.1)	6,288 (0.6)
Obesity	-4	27,146 (1.2)	14,625 (3.2)	13,618 (1.4)
Weight Loss	6	14,273 (0.6)	9,578 (2.1)	6,386 (0.6)
Fluid and Electrolyte Disorders	5	56,679 (2.6)	29,807 (6.6)	34,245 (3.4)
Blood Loss Anaemia	-2	465 (0.0)	311 (0.1)	289 (0.0)
Deficiency Anaemia	-2	25,765 (1.2)	13,074 (2.9)	12,549 (1.3)

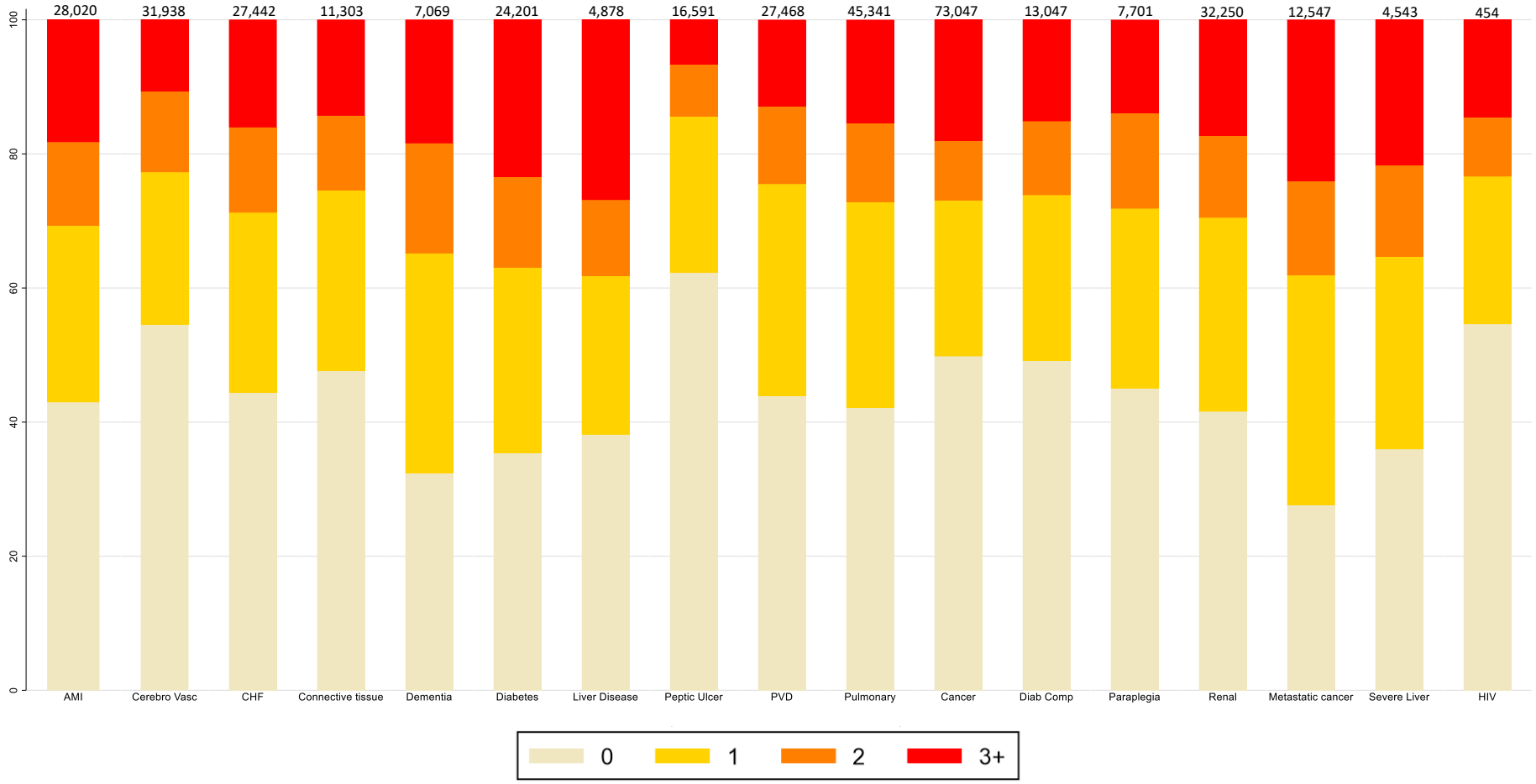
Elixhauser Component	Score weighting	Episodes, n (%)	Individuals, n (%)	Diagnostic-dominant episodes
Alcohol Abuse	0	39,588 (1.8)	16,056 (3.5)	28,107 (2.8)
Drug Abuse	-7	9,043 (0.4)	4,523 (1.0)	6,334 (0.6)
Psychoses	0	7,798 (0.4)	2,620 (0.6)	5,265 (0.5)
Depression	-3	66,447 (3.0)	31,935 (7.0)	45,229 (4.5)
Hypertension, Complicated	0	5,701 (0.3)	3,029 (0.7)	3,216 (0.3)

Supplementary Figure 1: Examples of individuals' Charlson and Elixhauser scores calculating using the DiagDom and the Lookback_1y method.

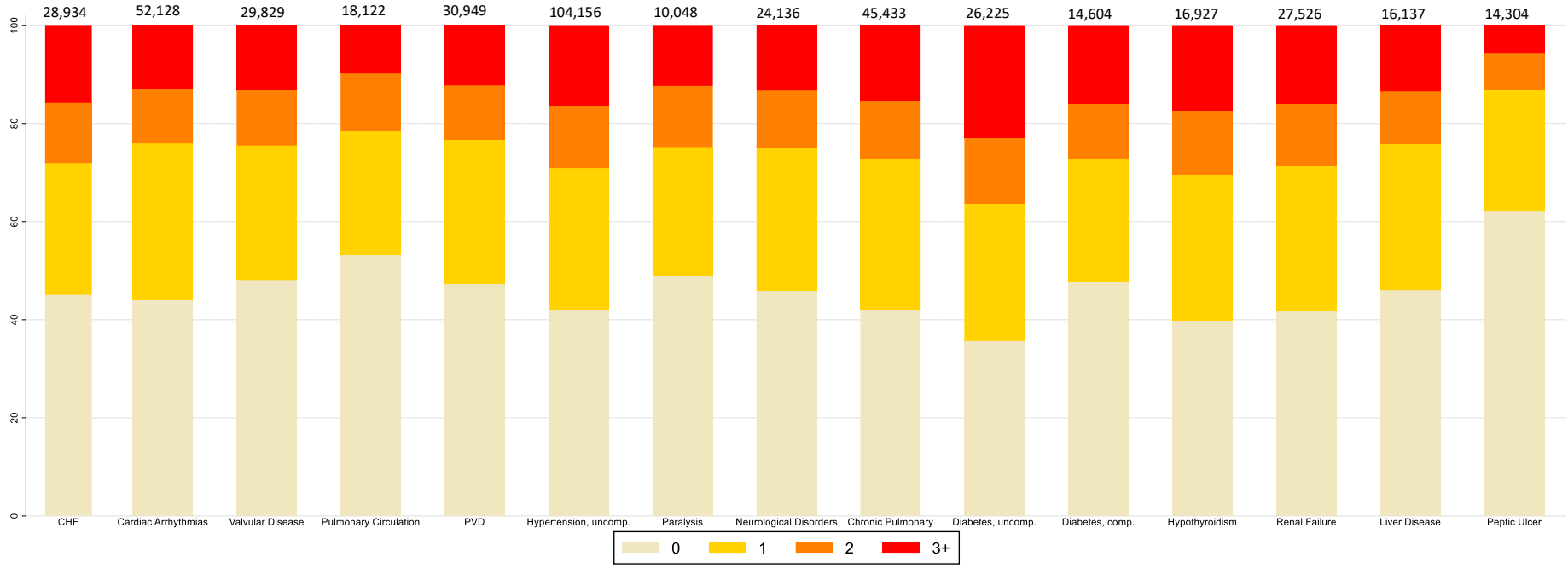


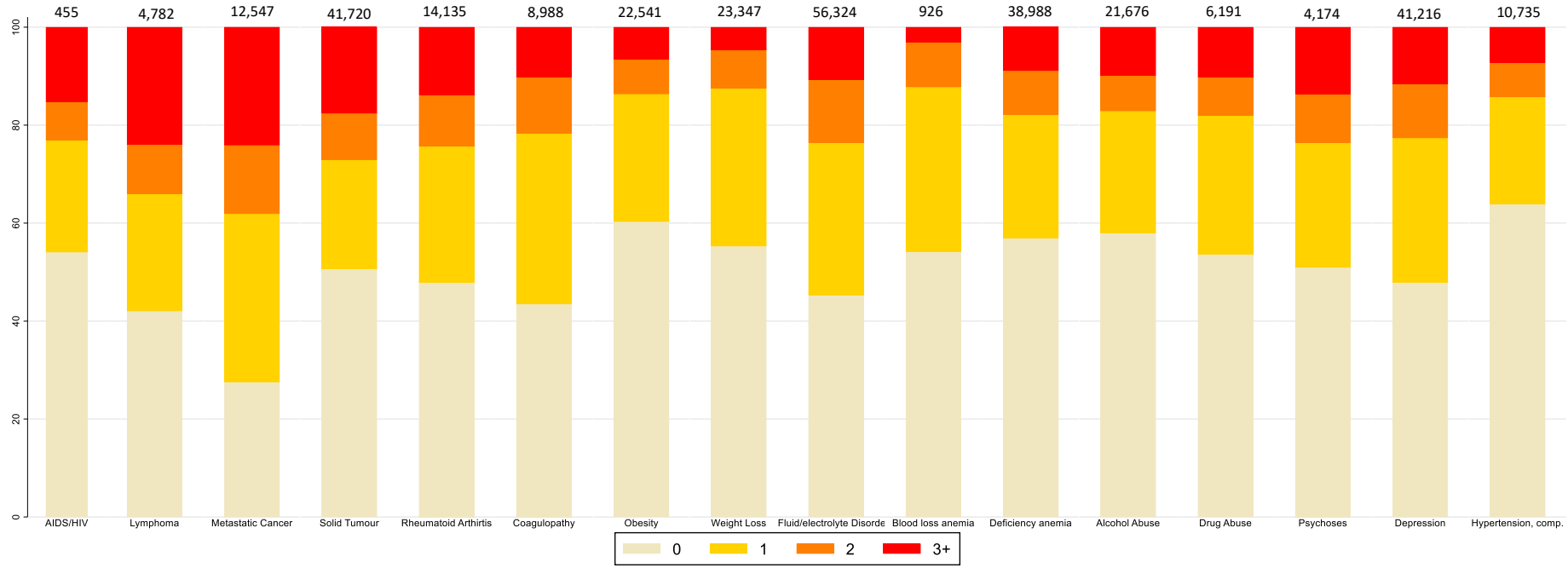
Supplementary Figure 2: Admissions in individuals who did not have a particular comorbiditiy code in the diagnostic-dominant episode but did have at some point earlier in the study period. Colours represent the number of comorbidity codes in the prior year which hence would have been included in the one-year lookback and not in diagnostic-dominant method.

A: Charlson Score



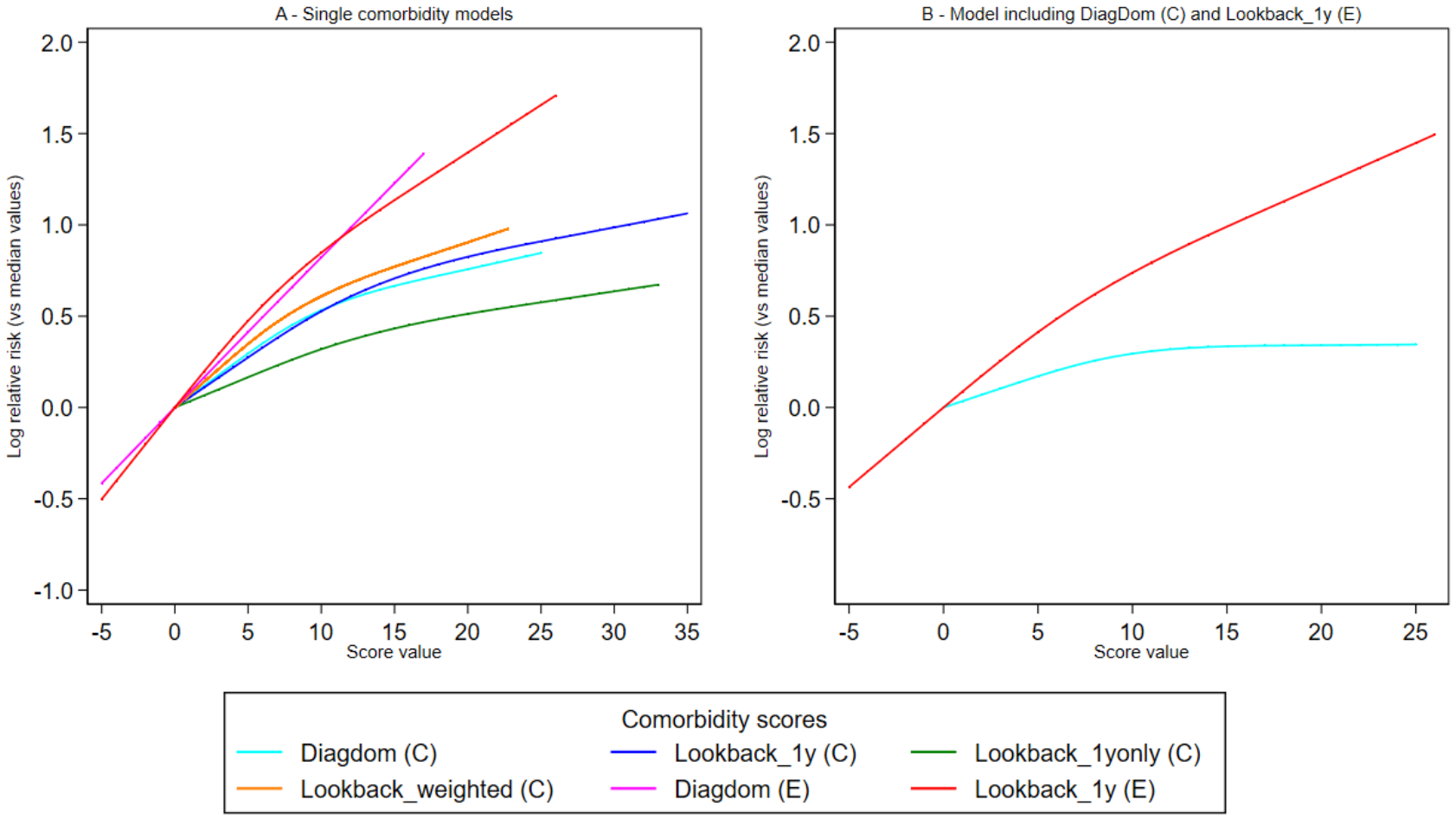
B – Elixhauser Score



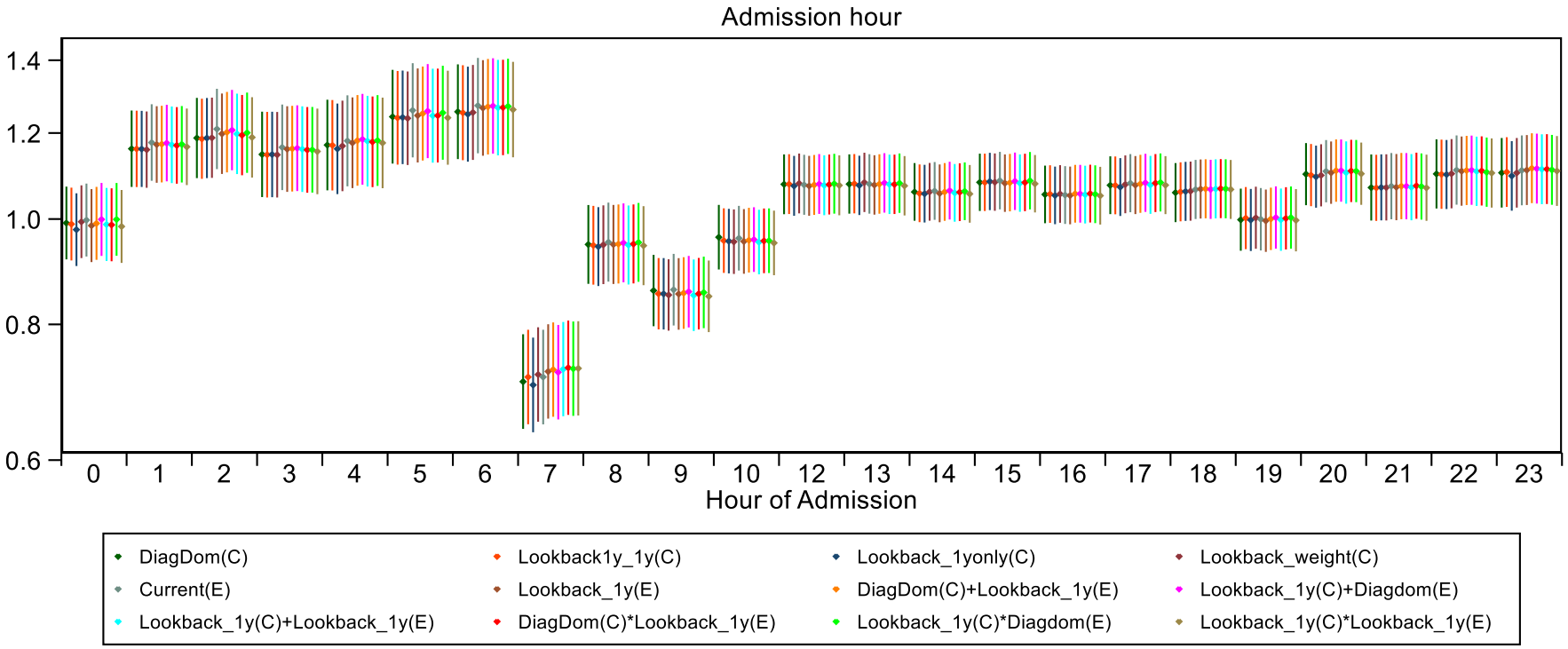


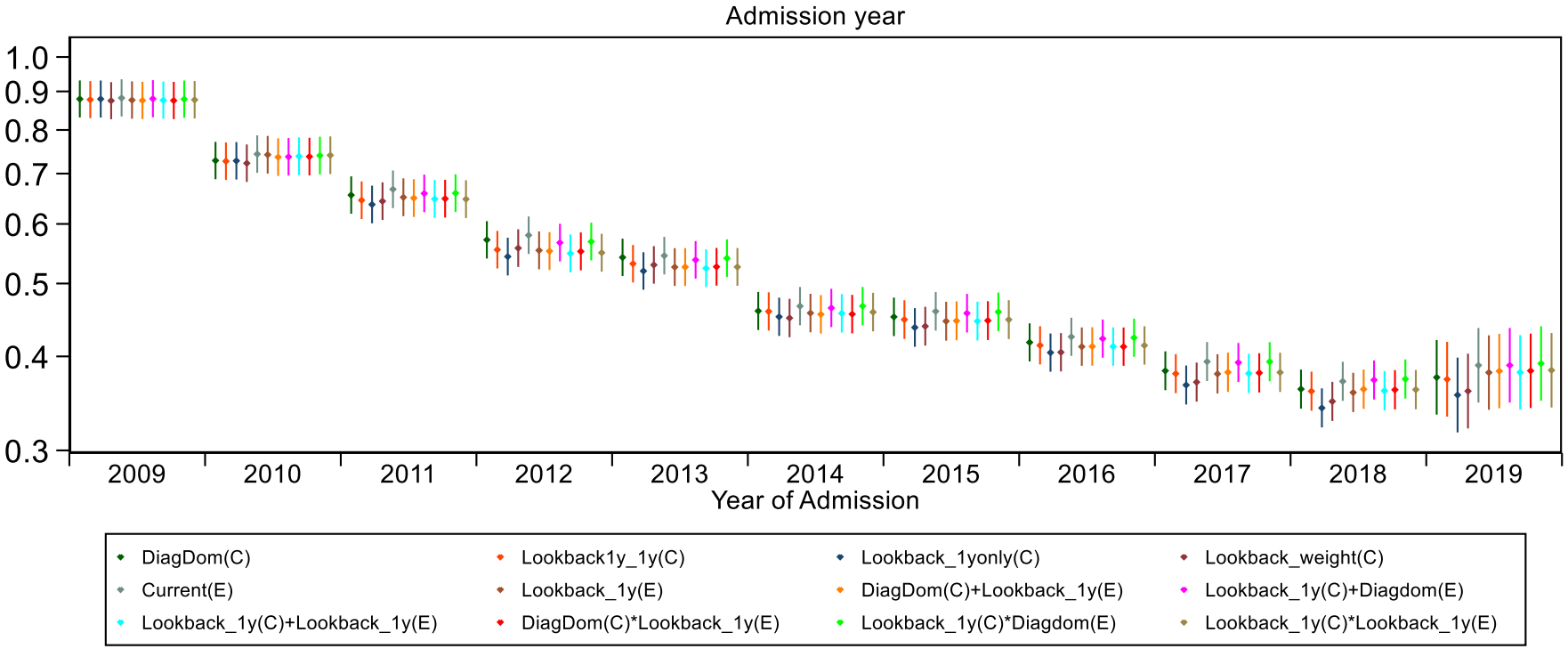
Note: Numbers on top of bars show the total number of diagnostic dominant admissions with no comorbidity-specific code, but at least one prior use of a relevant code in the study period.

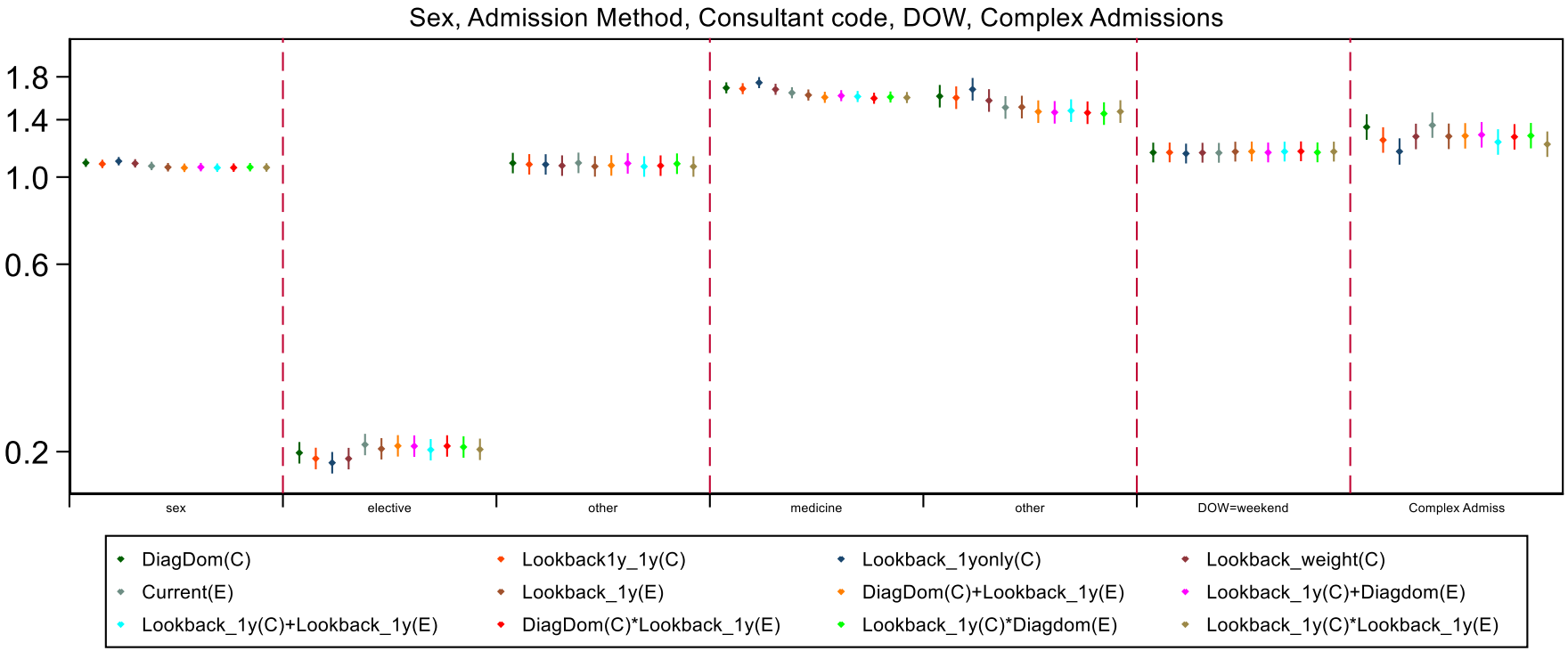
Supplementary Figure 3: Adjusted effects of Charlson (C) and Elixhauser (E) scores on 30-day mortality as main effects individually (left), and when the Charlson (DiagDom) and Elixhauser (Lookback_1y) score together as two main effects (right).

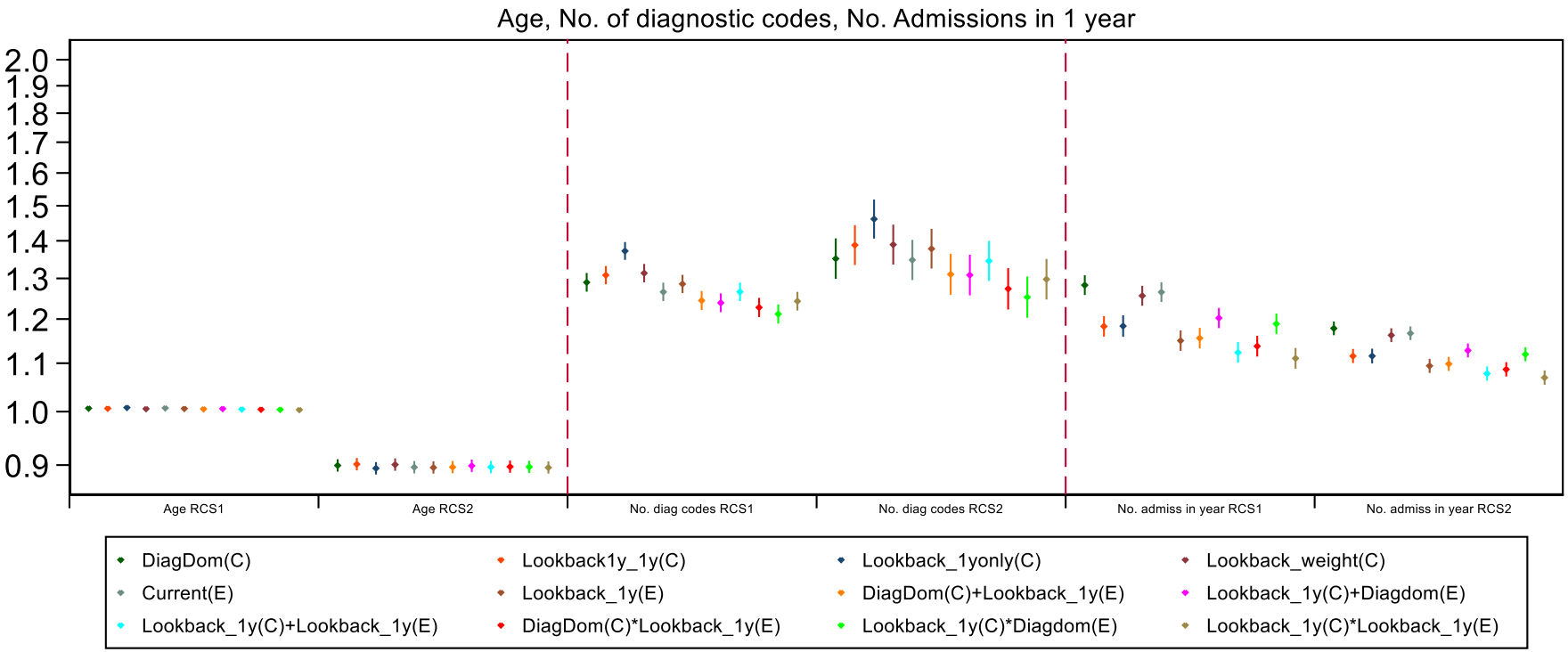


Supplementary Figure 4: Hazard ratios (95% CI) for other variables included in models with splines for comorbidity scores




Admission year
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year of Admission
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


Sex, Admission Method, Consultant code, DOW, Complex Admissions
1.8
1.4
1.0
0.6
0.2
sex
elective
other
medicine
other
DOW=weekend
Complex Admiss
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


Age, No. of diagnostic codes, No. Admissions in 1 year
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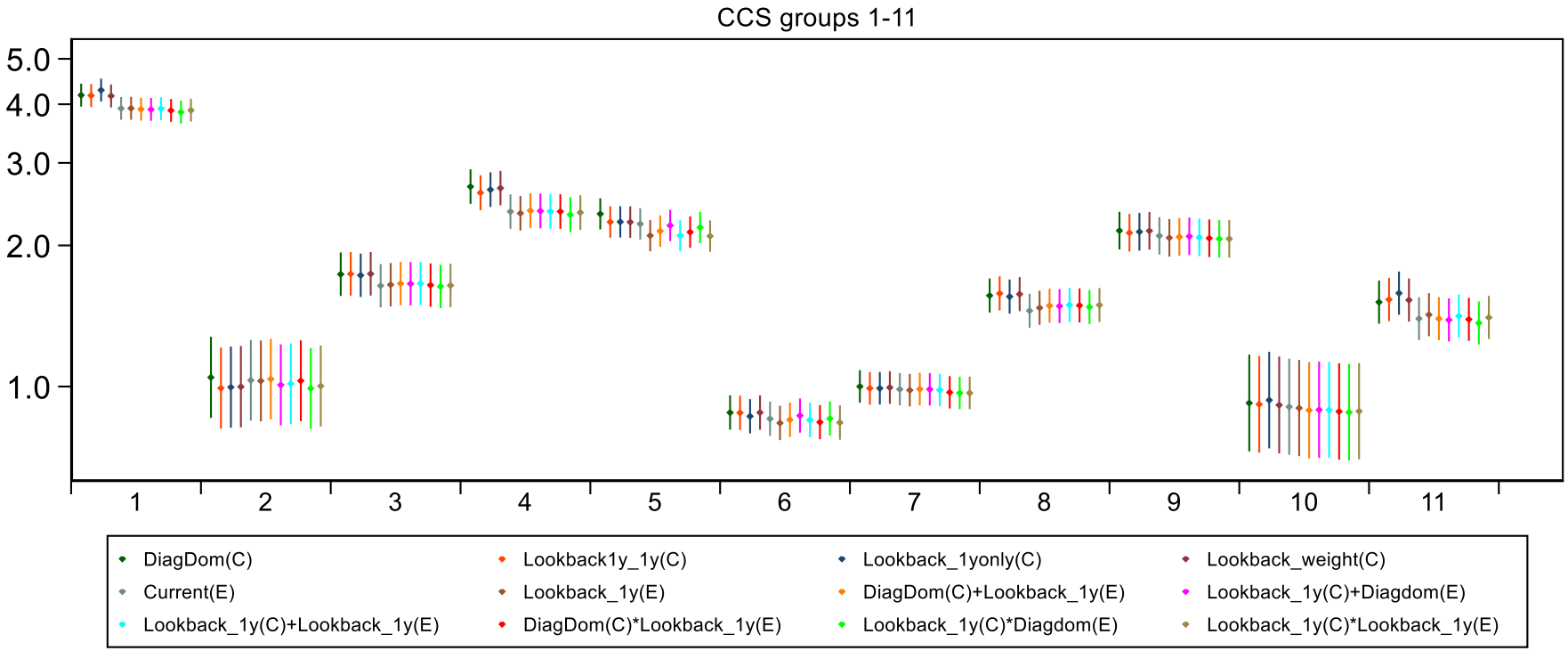
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
Age RCS1
Age RCS2
No. diag codes RCS1
No. diag codes RCS2
No. admiss in year RCS1
No. admiss in year RCS2
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


CCS groups 1-11
5.0
4.0
3.0
2.0
1.0
1
2
3
4
5
6
7
8
9
10
11
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
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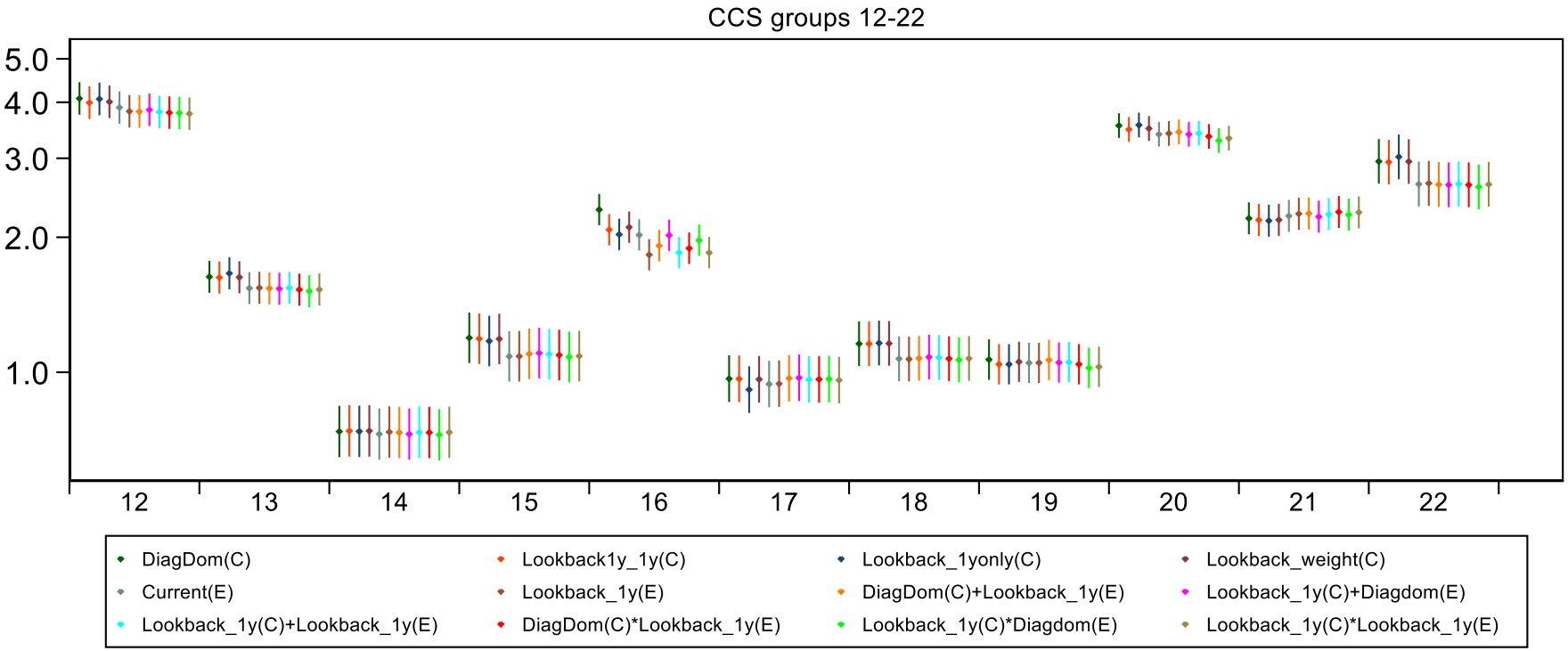
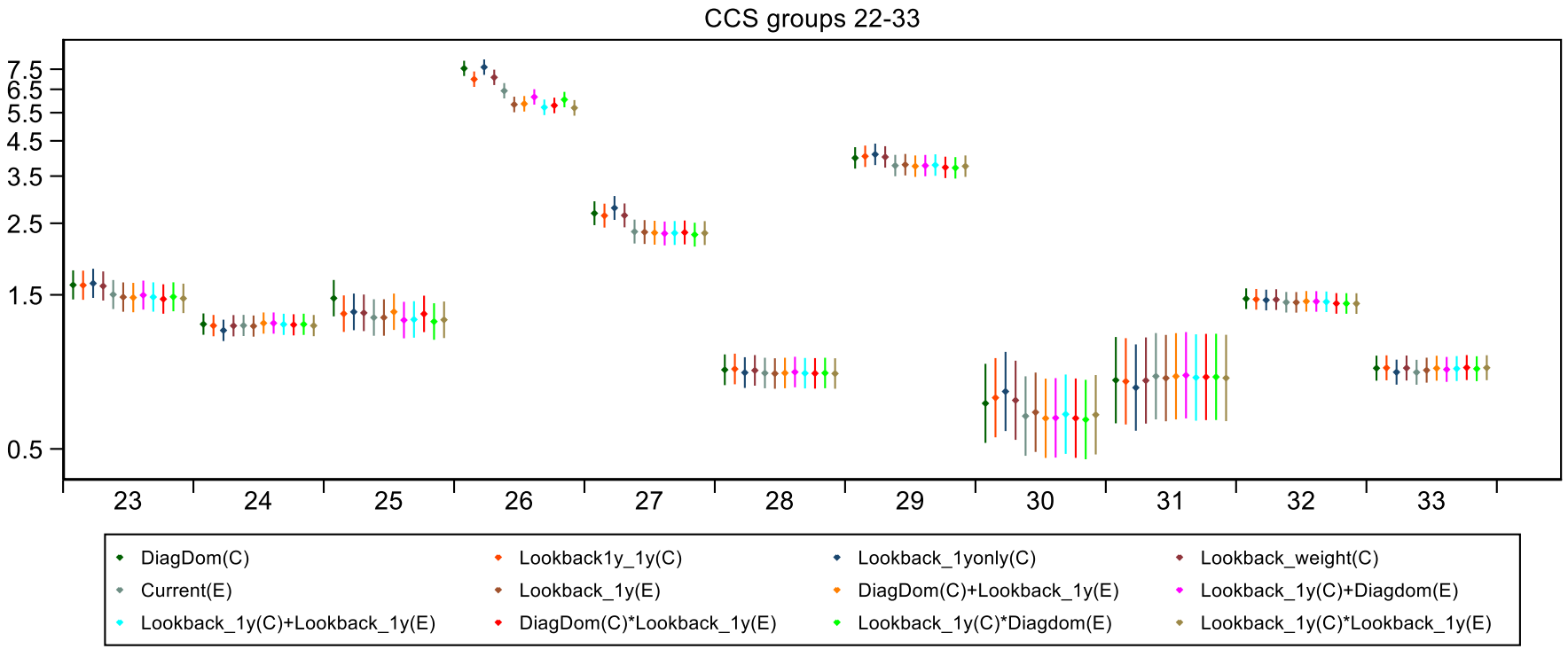
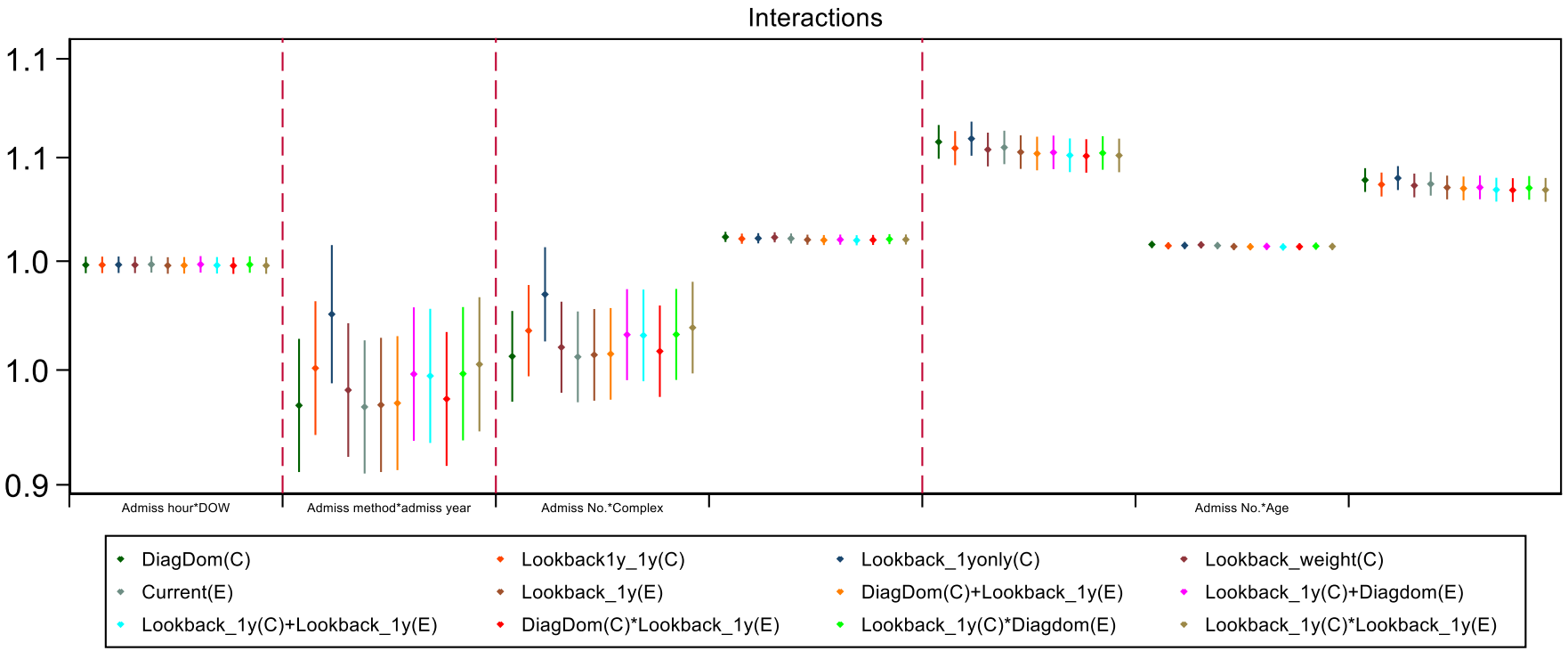
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


CCS groups 12-22
5.0
4.0
3.0
2.0
1.0
12
13
14
15
16
17
18
19
20
21
22
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


CCS groups 22-33
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
23
24
25
26
27
28
29
30
31
32
33
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)


Interactions
1.1
1.1
1.0
1.0
0.9
Admiss hour*DOW
Admiss method*admiss year
Admiss No.*Complex
Admiss No.*Age
DiagDom(C)
Lookback1y_1y(C)
Lookback_1yonly(C)
Lookback_weight(C)
Current(E)
Lookback_1y(E)
DiagDom(C)+Lookback_1y(E)
Lookback_1y(C)+Diagdom(E)
Lookback_1y(C)+Lookback_1y(E)
DiagDom(C)*Lookback_1y(E)
Lookback_1y(C)*Diagdom(E)
Lookback_1y(C)*Lookback_1y(E)

REFERENCE LIST

1. Walker AS, Mason A, Quan P, Fawcett NJ, Watkinson P, Llewelyn M, et al. Mortality risks associated with emergency admissions during weekends and public holidays: an analysis of electronic health records. wwwthelancetcom. 2017;390.

2. NHS Digital. About the Summary Hospital-level Mortality Indicator (SHMI) 2019 [Available from: https://digital.nhs.uk/data-and-information/publications/ci-hub/summary-hospital-level-mortality-indicator-shmi].