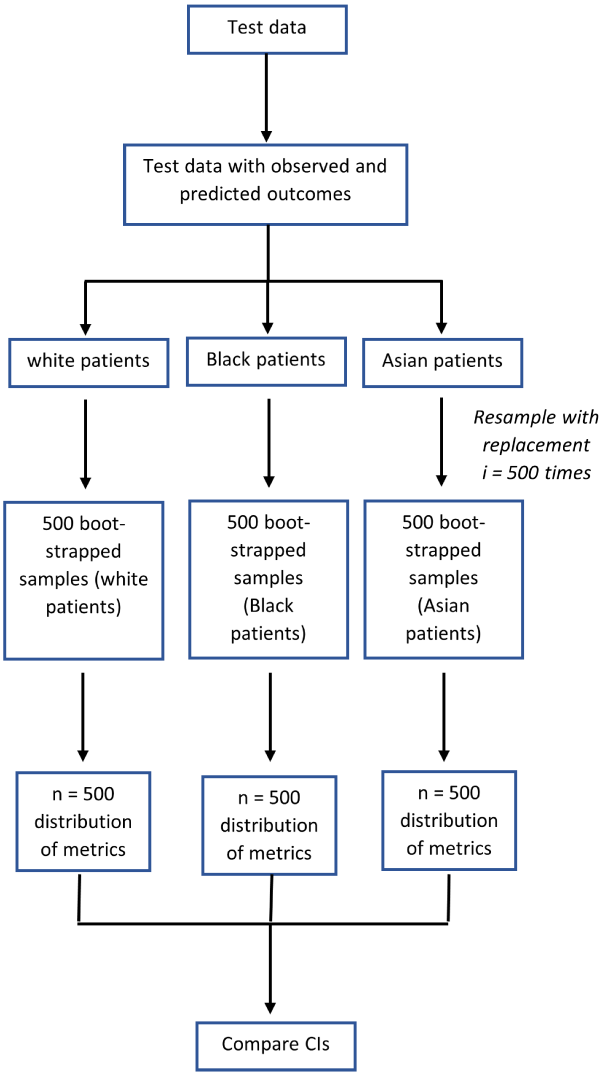
Appendix

Appendix Figure 1: Bootstrapping analytical workflow, exemplar patient race



CI = Confidence interval.

Appendix Table 1: Predictors and coefficients included in the Palliative Connect mortality prediction model

	Predictors	Coefficents
	(Intercept)	-4.09
	Age	0.70
	Female	-0.22
	Admission type urgent	1.29
Comorbidities	Metastatic cancer	0.23
	Alcohol use disorder	-0.08
	Weight loss	0.14
	Deficiency anemia	-0.10
	Lymphoma	0.17
	Pulmonary circulation disorders	0.06
	Obesity	-0.08
	Hypertension, uncomplicated	-0.16
	Fluid and electrolyte disorders	0.10
	Renal failure	-0.06
	Other neurologic disorders	0.06
	Peripheral vascular disorders	0.04
	Hypothyroidism	-0.04
	Congestive heart failure	0.14
	Depression	-0.07
	Drug use disorder	-0.10
	Coagulopathy	0.10
	Solid tumor without metastasis	0.32
Lab values	Anion gap	0.23
	Blood urea nitrogen	0.33
	Total calcium	0.44
	Carbon dioxide	0.49
	Chloride	0.23
	Creatinine	0.36
	Glucose	0.13
	Hemoglobin	0.18
	Mean cell volume	0.15
	Platelet	0.62
	Potassium	0.23
	Red cell distribution width	0.11
	Sodium	0.45
	White blood cell	0.49

Appendix Table 2: Model predictive performance for each patient subgroup, threshold for triggered palliative care consultation set at predicted probability of 6 month mortality = 0.3

			accuracy		FPR		FNR		Brier		C-statistic		ICI	
	subgroup	n	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Age	Reference: Oldest	10,331	0.696	(0.688, 0.705)	0.287	(0.276, 0.297)	0.378	(0.357, 0.398)	0.145	(0.140, 0.149)	0.723	(0.714, 0.732)	0.045	(0.039, 0.050)
	3rd quartile	10,332	0.795*	(0.786, 0.804)	0.178*	(0.107, 0.189)	0.361	(0.336, 0.388)	0.106*	(0.101, 0.110)	0.784*	(0.774, 0.793)	0.015*	(0.011, 0.021)
	2nd quartile	10,332	0.867*	(0.859, 0.874)	0.096*	(0.088, 0.103)	0.419*	(0.390, 0.453)	0.082*	(0.077, 0.087)	0.835*	(0.823, 0.845)	0.019*	(0.016, 0.024)
	Youngest	10,332	0.949*	(0.945, 0.953)	0.022*	(0.019, 0.025)	0.710*	(0.670, 0.753)	0.036*	(0.033, 0.038)	0.798*	(0.775, 0.814)	0.009*	(0.006, 0.012)
Race	Reference: non-Hispanic white	22,072	0.814	(0.808, 0.821)	0.159	(0.152, 0.165)	0.384	(0.367, 0.399)	0.092	(0.089, 0.095)	0.812	(0.807, 0.818)	0.016	(0.013, 0.019)
	Asian	1,646	0.796	(0.768, 0.818)	0.190	(0.158, 0.221)	0.276*	(0.196, 0.364)	0.109	(0.092, 0.122)	0.837	(0.805, 0.865)	0.038*	(0.019, 0.057)
	Black or African-American	14,428	0.865*	(0.860, 0.871)	0.099*	(0.094, 0.105)	0.433*	(0.412, 0.457)	0.080*	(0.077, 0.083)	0.823*	(0.813, 0.833)	0.013	(0.010, 0.016)
Ethnicity	Reference: non-Hispanic white	22,072	0.814	(0.808, 0.821)	0.159	(0.152, 0.165)	0.384	(0.367, 0.399)	0.092	(0.089, 0.095)	0.812	(0.807, 0.818)	0.016	(0.013, 0.019)
	Hispanic	1,299	0.846*	(0.826, 0.867)	0.092*	(0.073, 0.110)	0.603*	(0.507, 0.685)	0.093	(0.079, 0.106)	0.813	(0.787, 0.841)	0.036*	(0.025, 0.050)
Sex assigned at birth	Reference: male	20,511	0.824	(0.819, 0.830)	0.146	(0.140, 0.151)	0.405	(0.389, 0.422)	0.089	(0.086, 0.092)	0.809	(0.802, 0.815)	0.017	(0.015, 0.020)
	female	20,816	0.854*	(0.849, 0.859)	0.108*	(0.102, 0.114)	0.433	(0.411, 0.452)	0.085*	(0.082, 0.088)	0.824*	(0.816, 0.831)	0.014	(0.012, 0.018)
Insurance	Reference: Medicare	18,355	0.763	(0.756, 0.769)	0.204	(0.198, 0.211)	0.410	(0.395, 0.428)	0.121	(0.118, 0.124)	0.759	(0.752, 0.766)	0.028	(0.024, 0.032)
	Managed care	11,082	0.883*	(0.876, 0.891)	0.095*	(0.087, 0.102)	0.334*	(0.305, 0.356)	0.065*	(0.062, 0.069)	0.858*	(0.850, 0.866)	0.014*	(0.011, 0.017)
	Medicaid	6,676	0.917*	(0.901, 0.924)	0.048*	(0.043, 0.055)	0.569*	(0.522, 0.611)	0.052*	(0.049, 0.056)	0.830*	(0.815, 0.846)	0.009*	(0.007, 0.012)
	Private	3,810	0.877*	(0.867, 0.889)	0.092*	(0.081, 0.102)	0.417	(0.365, 0.469)	0.071*	(0.065, 0.078)	0.850*	(0.831, 0.866)	0.015*	(0.010, 0.021)
	Missing	1,404	0.931*	(0.922, 0.940)	0.034*	(0.026, 0.042)	0.594*	(0.520, 0.668)	0.05*	(0.043, 0.057)	0.874*	(0.850, 0.894)	0.024	(0.016, 0.033)
Household income	Reference: Highest	10,265	0.801	(0.792, 0.810)	0.183	(0.173, 0.192)	0.312	(0.285, 0.339)	0.093	(0.089, 0.098)	0.818	(0.808, 0.827)	0.017	(0.013, 0.022)
	3rd quartile	10,265	0.83*	(0.822, 0.840)	0.132*	(0.123, 0.140)	0.453*	(0.422, 0.485)	0.092	(0.088, 0.095)	0.804	(0.796, 0.814)	0.018	(0.013, 0.022)
	2nd quartile	10,265	0.835*	(0.827, 0.842)	0.129*	(0.120, 0.136)	0.391*	(0.371, 0.417)	0.096	(0.092, 0.100)	0.829	(0.819, 0.839)	0.026*	(0.021, 0.031)
	Lowest	10,266	0.854*	(0.846, 0.861)	0.106*	(0.099, 0.111)	0.499*	(0.468, 0.527)	0.082*	(0.078, 0.086)	0.800*	(0.789, 0.811)	0.012*	(0.009, 0.016)
Educational attainment	Reference: Highest	10,276	0.806	(0.798, 0.817)	0.176	(0.165, 0.183)	0.324	(0.298, 0.354)	0.092	(0.088, 0.096)	0.828	(0.819, 0.837)	0.019	(0.015, 0.023)
	3rd quartile	10,276	0.818*	(0.810, 0.826)	0.146*	(0.136, 0.154)	0.448*	(0.420, 0.479)	0.096	(0.092, 0.100)	0.791*	(0.781, 0.801)	0.022	(0.017, 0.027)
	2nd quartile	10,276	0.832*	(0.824, 0.841)	0.124*	(0.116, 0.132)	0.434*	(0.406, 0.461)	0.101*	(0.097, 0.106)	0.797*	(0.783, 0.809)	0.026	(0.021, 0.031)
	Lowest	10,276	0.867*	(0.859, 0.874)	0.097*	(0.091, 0.104)	0.460*	(0.434, 0.487)	0.074*	(0.070, 0.077)	0.834	(0.827, 0.844)	0.011*	(0.008, 0.014)

***** indicates that the bootstrapped 95% CI of the subgroup minus reference group difference for each metric does not include zero.

Abbreviations: FPR = false positive rate, FNR = false negative rate, ICI = integrated calibration index. Age quartiles comprised: youngest (18.1 – 47.8 years) 2nd quartile (47.8 – 60.8 years), 3rd quartile (60.8 – 71.2 years) and oldest (71.2 – ≥90 years). Zip code level median household income

quartiles comprised: lowest quartile ($11,269 - $33,117) 2nd quartile ($33,117 - $58,784) 3rd quartile ($58,784 - $80,363) and highest quartile ($80,363 - $225,598). Zip code level educational attainment (proportion of residents >= 25 years old who completed at least a bachelor's degree, inclusive of all higher levels) quartiles comprised: lowest quartile (0% - 21.9%), 2nd quartile (21.9% - 28.6%), 3rd quartile (28.6% - 48.7%), and highest quartile (48.8% - 100%).

Appendix Table 3: Model predictive performance for entire test cohort, threshold for triggered palliative care consultation set at predicted probability of 6 month mortality = 0.3

		accuracy		FPR		FNR		Brier		C-statistic		ICI	
group	n	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Test cohort	41,327	0.839	(0.835, 0.844)	0.128	(0.123, 0.131)	0.419	(0.406, 0.435)	0.087	(0.085, 0.089)	0.816	(0.811, 0.821)	0.014	(0.012, 0.015)

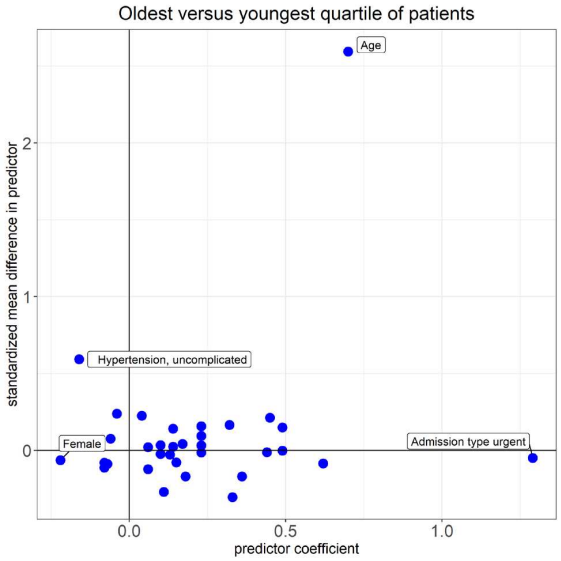
Abbreviations: FPR = false positive rate, FNR = false negative rate, ICI = integrated calibration index. Age quartiles comprised: youngest (18.1 – 47.8 years) 2nd quartile (47.8 – 60.8 years), 3rd quartile (60.8 – 71.2 years) and oldest (71.2 – ≥90 years). Zip code level median household income quartiles comprised: lowest quartile ($11,269 - $33,117) 2nd quartile ($33,117 - $58,784) 3rd quartile ($58,784 - $80,363) and highest quartile ($80,363 - $225,598). Zip code level educational attainment (proportion of residents >= 25 years old who completed at least a bachelor's degree, inclusive of all higher levels) quartiles comprised: lowest quartile (0% - 21.9%), 2nd quartile (21.9% - 28.6%), 3rd quartile (28.6% - 48.7%), and highest quartile (48.8% - 100%).

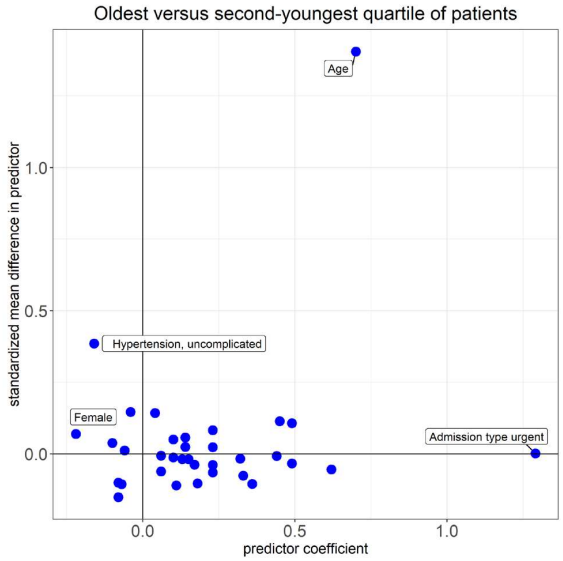
Appendix Table 4: Model predictive performance for each patient subgroup, threshold for triggered palliative care consultation set at predicted probability of 6 month mortality = 0.5

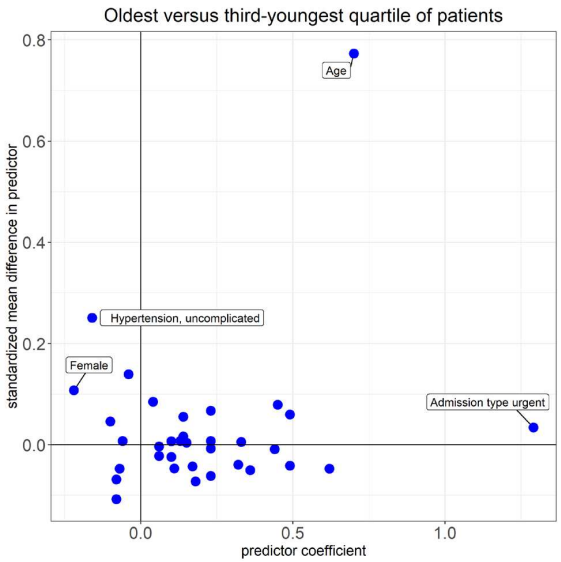
			accuracy		FPR		FNR		Brier		C-statistic		ICI	
	subgroup	n	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI	mean	95% CI
Age	Reference: Oldest	10,331	0.780	(0.771, 0.788)	0.121	(0.113, 0.130)	0.659	(0.637, 0.682)	0.144	(0.140, 0.149)	0.722	(0.713, 0.731)	0.045	(0.039, 0.050)
	3rd quartile	10,332	0.846*	(0.838, 0.854)	0.069*	(0.062, 0.075)	0.651	(0.627, 0.679)	0.105*	(0.101, 0.110)	0.784*	(0.773, 0.794)	0.015*	(0.010, 0.019)
	2nd quartile	10,332	0.890*	(0.882, 0.896)	0.042*	(0.037, 0.047)	0.645	(0.615, 0.678)	0.082*	(0.077, 0.086)	0.834*	(0.823, 0.844)	0.019*	(0.015, 0.024)
	Youngest	10,332	0.961*	(0.957, 0.964)	0.002*	(0.001, 0.003)	0.891*	(0.863, 0.916)	0.036*	(0.033, 0.038)	0.797*	(0.777, 0.815)	0.009*	(0.007, 0.012)
Race	Reference: non-Hispanic white	22,072	0.861	(0.856, 0.866)	0.068	(0.064, 0.073)	0.654	(0.635, 0.675)	0.092	(0.089, 0.095)	0.812	(0.806, 0.819)	0.016	(0.013, 0.019)
	Asian	1,646	0.850	(0.819, 0.873)	0.084	(0.064, 0.108)	0.473*	(0.376, 0.569)	0.109*	(0.094, 0.123)	0.837	(0.806, 0.861)	0.039*	(0.020, 0.057)
	Black or African-American	14,428	0.894*	(0.889, 0.899)	0.036*	(0.033, 0.040)	0.695*	(0.670, 0.719)	0.080*	(0.077, 0.083)	0.823*	(0.813, 0.832)	0.013	(0.010, 0.016)
Ethnicity	Reference: non-Hispanic white	22,072	0.861	(0.856, 0.866)	0.068	(0.064, 0.073)	0.654	(0.635, 0.675)	0.092	(0.089, 0.095)	0.812	(0.806, 0.819)	0.016	(0.013, 0.019)
	Hispanic	1,299	0.892*	(0.875, 0.910)	0.009*	(0.005, 0.016)	0.813*	(0.739, 0.882)	0.093	(0.080, 0.107)	0.813	(0.787, 0.836)	0.037*	(0.024, 0.050)
Sex assigned at birth	Reference: male	20,511	0.872	(0.867, 0.877)	0.059	(0.055, 0.064)	0.658	(0.637, 0.676)	0.089	(0.086, 0.092)	0.809	(0.802, 0.815)	0.017	(0.015, 0.020)
	female	20,816	0.883*	(0.879, 0.888)	0.041*	(0.038, 0.045)	0.699*	(0.677, 0.721)	0.084*	(0.082, 0.087)	0.824*	(0.816, 0.831)	0.014	(0.011, 0.018)
Insurance	Reference: Medicare	18,355	0.827	(0.820, 0.832)	0.080	(0.075, 0.085)	0.668	(0.649, 0.687)	0.121	(0.117, 0.124)	0.758	(0.750, 0.766)	0.028	(0.024, 0.032)
	Managed care	11,082	0.916*	(0.910, 0.922)	0.029*	(0.025, 0.033)	0.640	(0.610, 0.670)	0.065*	(0.062, 0.069)	0.858*	(0.849, 0.867)	0.014*	(0.012, 0.017)
	Medicaid	6,676	0.928*	(0.922, 0.934)	0.021*	(0.017, 0.025)	0.780*	(0.743, 0.813)	0.052*	(0.049, 0.056)	0.830*	(0.815, 0.845)	0.009*	(0.006, 0.012)
	Private	3,810	0.882*	(0.871, 0.893)	0.062*	(0.052, 0.073)	0.650	(0.598, 0.707)	0.071*	(0.065, 0.077)	0.849*	(0.832, 0.865)	0.015*	(0.010, 0.020)
	Missing	1,404	0.933*	(0.923, 0.943)	0.017*	(0.010, 0.024)	0.809*	(0.751, 0.868)	0.050*	(0.042, 0.057)	0.874*	(0.849, 0.896)	0.024	(0.016, 0.034)
Household income	Reference: Highest	10,265	0.856	(0.848, 0.864)	0.076	(0.068, 0.083)	0.629	(0.599, 0.662)	0.093	(0.089, 0.098)	0.817	(0.808, 0.827)	0.017	(0.014, 0.022)
	3rd quartile	10,265	0.863	(0.856, 0.870)	0.058*	(0.051, 0.064)	0.723*	(0.694, 0.747)	0.092	(0.088, 0.096)	0.803	(0.794, 0.813)	0.018	(0.014, 0.023)
	2nd quartile	10,265	0.878*	(0.871, 0.885)	0.045*	(0.040, 0.051)	0.605	(0.572, 0.639)	0.096	(0.092, 0.101)	0.829	(0.819, 0.839)	0.025*	(0.019, 0.031)
	Lowest	10,266	0.887*	(0.881, 0.894)	0.040*	(0.036, 0.045)	0.752*	(0.730, 0.774)	0.082*	(0.078, 0.085)	0.800*	(0.789, 0.810)	0.012*	(0.009, 0.016)
Educational attainment	Reference: Highest	10,276	0.856	(0.848, 0.864)	0.073	(0.066, 0.080)	0.649	(0.620, 0.679)	0.092	(0.087, 0.096)	0.827	(0.819, 0.836)	0.020	(0.016, 0.024)
	3rd quartile	10,276	0.860	(0.853, 0.868)	0.065	(0.059, 0.071)	0.695*	(0.669, 0.721)	0.095	(0.091, 0.099)	0.790*	(0.781, 0.800)	0.022	(0.017, 0.027)
	2nd quartile	10,276	0.867*	(0.860, 0.874)	0.050*	(0.045, 0.056)	0.644	(0.614, 0.673)	0.101*	(0.097, 0.106)	0.797*	(0.784, 0.809)	0.026	(0.021, 0.032)
	Lowest	10,276	0.902*	(0.896, 0.908)	0.030*	(0.026, 0.033)	0.731*	(0.703, 0.758)	0.073*	(0.070, 0.077)	0.834	(0.824, 0.843)	0.011*	(0.008, 0.014)

***** indicates that the bootstrapped 95% CI of the subgroup minus reference group difference for each metric does not include zero.
Abbreviations: FPR = false positive rate, FNR = false negative rate, ICI = integrated calibration index. Age quartiles comprised: youngest (18.1 – 47.8 years) 2nd quartile (47.8 – 60.8 years), 3rd quartile (60.8 – 71.2 years) and oldest (71.2 – ≥90 years). Zip code level median household income quartiles comprised: lowest quartile ($11,269 - $33,117) 2nd quartile ($33,117 - $58,784) 3rd quartile ($58,784 - $80,363) and highest quartile ($80,363 - $225,598). Zip code level educational attainment (proportion of residents >= 25 years old who completed at least a bachelor's degree, inclusive of all higher levels) quartiles comprised: lowest quartile (0% - 21.9%), 2nd quartile (21.9% - 28.6%), 3rd quartile (28.6% - 48.7%), and highest quartile (48.8% - 100%).

Appendix Figure 2: Original mortality risk model predictor coefficients versus the standardized mean difference in predictors, reference group minus subgroup, by age quartile

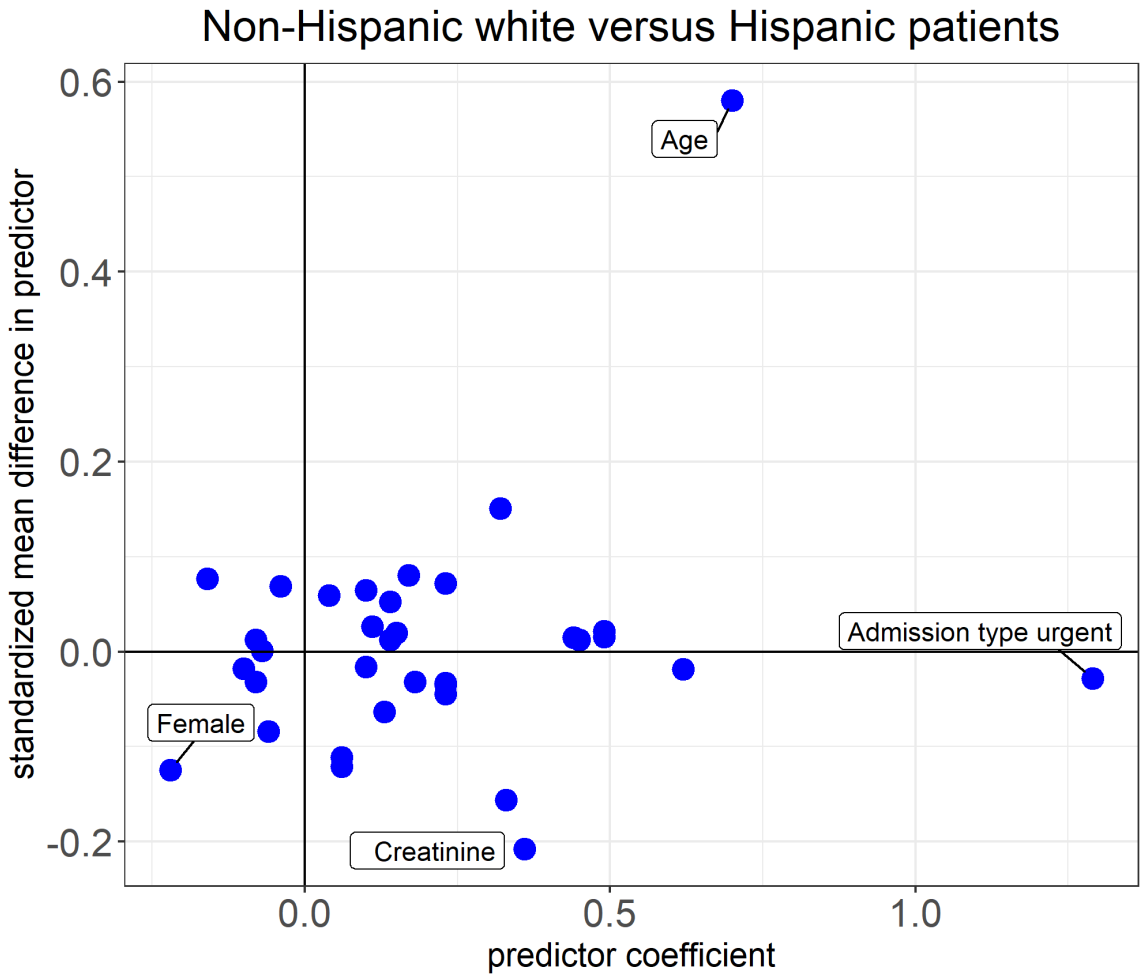

Oldest versus youngest quartile of patients
standardized mean difference in predictor
predictor coefficient
Age
Hypertension, uncomplicated
Female
Admission type urgent
0
1
2
0.0
0.5
1.0


Oldest versus second-youngest quartile of patients
standardized mean difference in predictor
predictor coefficient
Age
Hypertension, uncomplicated
Female
Admission type urgent
0.0
0.5
1.0
0.0
0.5
1.0

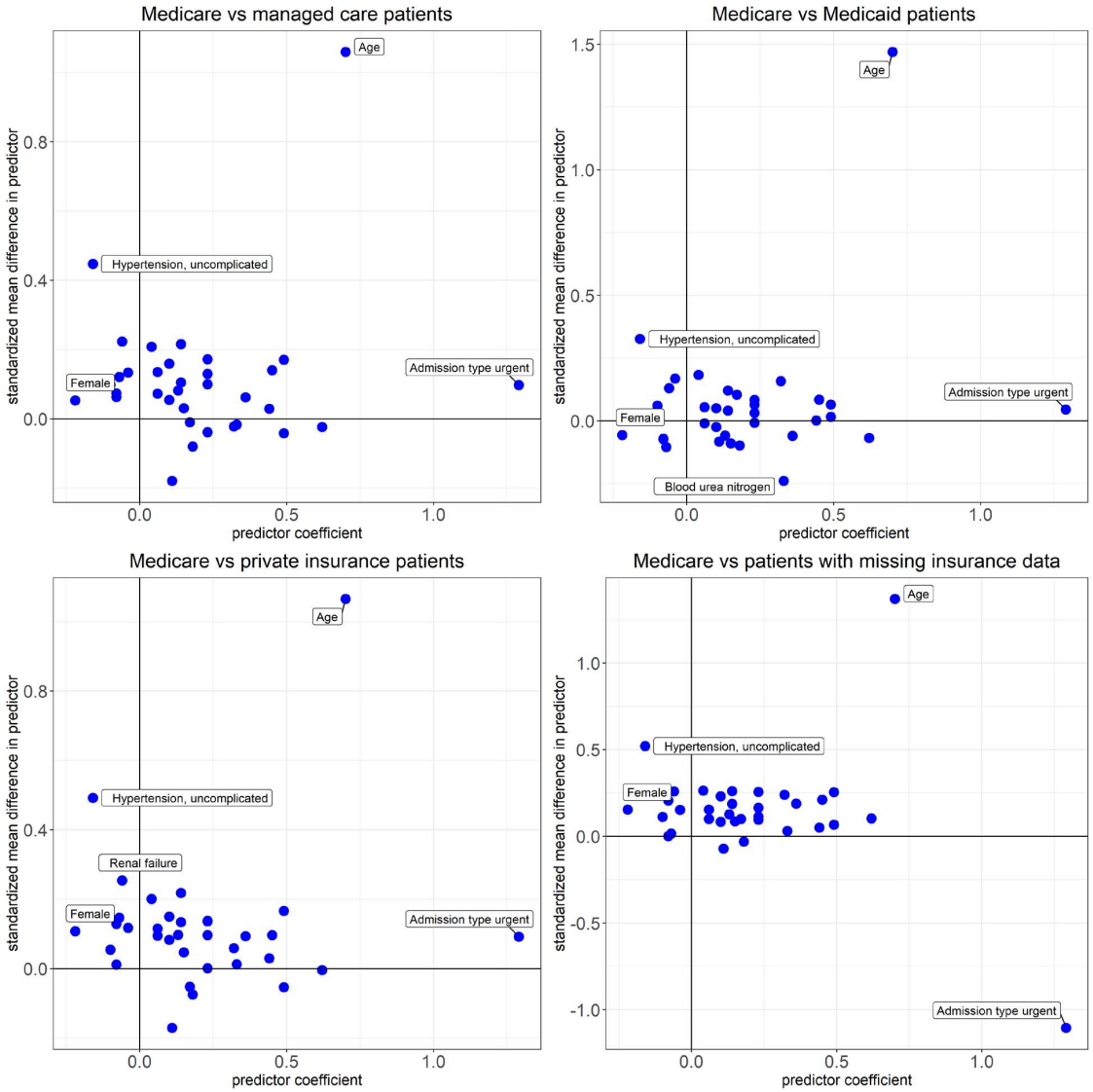

Oldest versus third-youngest quartile of patients
standardized mean difference in predictor
predictor coefficient
Age
Hypertension, uncomplicated
Female
Admission type urgent
0.0
0.2
0.4
0.6
0.8
0.0
0.5
1.0

All 34 predictors included in the original EHR-based mortality risk model are represented in this plot. Variable coefficient estimates are represented on the x-axis; standardized mean difference (difference between the two group means divided by the standard deviation of the variable) is represented on the y-axis.

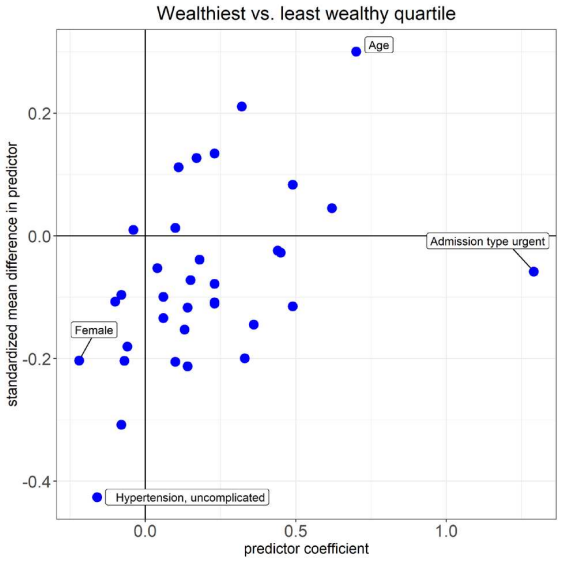
Appendix Figure 3: Original mortality risk model predictor coefficients versus the standardized mean difference in predictors, reference group minus subgroup, by ethnicity



Appendix Figure 4: Original mortality risk model predictor coefficients versus the standardized mean difference in predictors, reference group minus subgroup, by insurance status


Medicare vs managed care patients
Age
Hypertension, uncomplicated
Female
Admission type urgent
standardized mean difference in predictor
predictor coefficient
Medicare vs Medicaid patients
Age
Hypertension, uncomplicated
Female
Blood urea nitrogen
Admission type urgent
standardized mean difference in predictor
predictor coefficient
Medicare vs private insurance patients
Age
Hypertension, uncomplicated
Renal failure
Female
Admission type urgent
standardized mean difference in predictor
predictor coefficient
Medicare vs patients with missing insurance data
Age
Hypertension, uncomplicated
Female
Admission type urgent
standardized mean difference in predictor
predictor coefficient

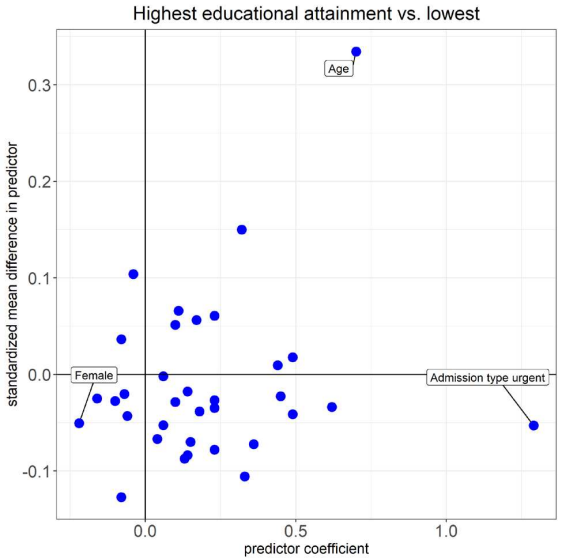
Appendix Figure 5: Original mortality risk model predictor coefficients versus the standardized mean difference in predictors, reference group minus subgroup, by household income quartile

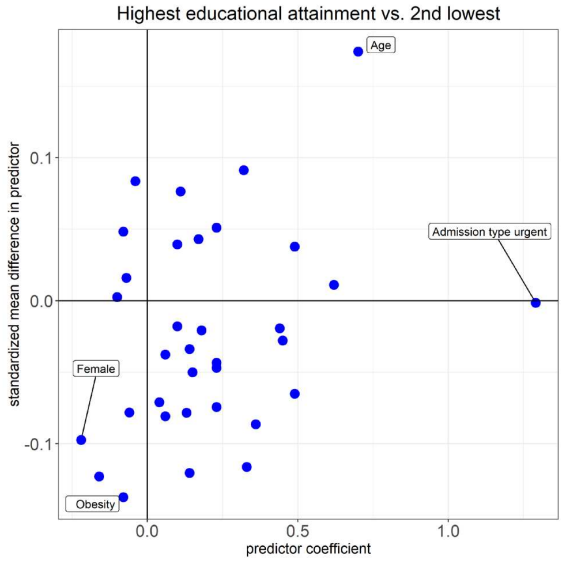

Wealthiest vs. least wealthy quartile
standardized mean difference in predictor
predictor coefficient
Age
Admission type urgent
Female
Hypertension, uncomplicated
0.2
0.0
-0.2
-0.4
0.0
0.5
1.0

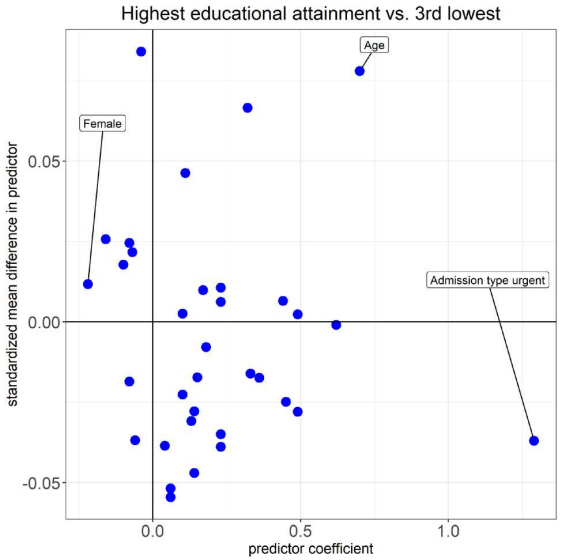
Wealthiest vs. 2nd-least wealthy quartile
standardized mean difference in predictor
predictor coefficient
Age
Female
Admission type urgent
0.2
0.1
0.0
-0.1
0.0
0.5
1.0

Wealthiest vs. 3rd-least wealthy quartile
standardized mean difference in predictor
predictor coefficient
Age
Female
Admission type urgent
0.10
0.05
0.00
-0.05
0.0
0.5
1.0

Appendix Figure 6: Original mortality risk model predictor coefficients versus the standardized mean difference in predictors, reference group minus subgroup, by educational attainment quartile


Highest educational attainment vs. lowest
standardized mean difference in predictor
predictor coefficient
Age
Female
Admission type urgent
0.3
0.2
0.1
0.0
-0.1
0.0
0.5
1.0


Highest educational attainment vs. 2nd lowest
standardized mean difference in predictor
predictor coefficient
Age
Admission type urgent
Female
Obesity
0.1
0.0
-0.1
0.0
0.5
1.0


Highest educational attainment vs. 3rd lowest
standardized mean difference in predictor
predictor coefficient
Age
Female
Admission type urgent
0.05
0.00
-0.05
0.0
0.5
1.0