

## Appendix

Figure A1. High-low plot of the proportion of admissions for COVID-19 that ended in death among English hospitals by month of admission

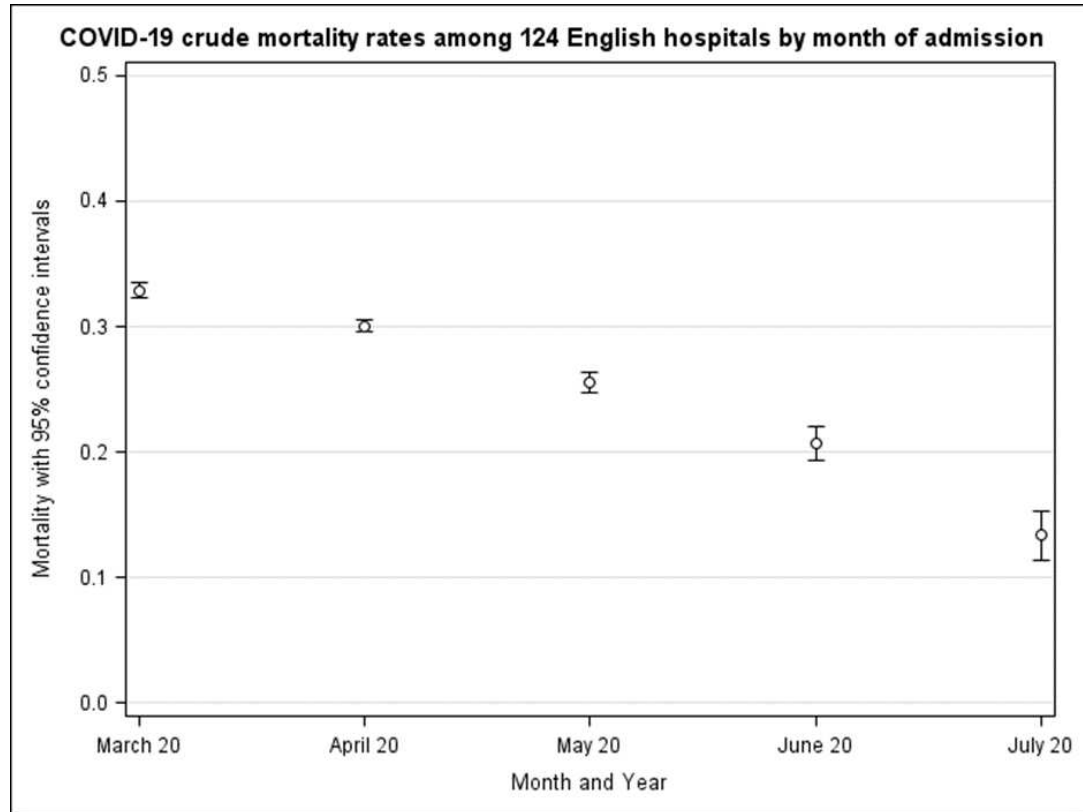


Figure A2. Funnel plot for the crude COVID-19 mortality rates for the early period (March to April 2020)

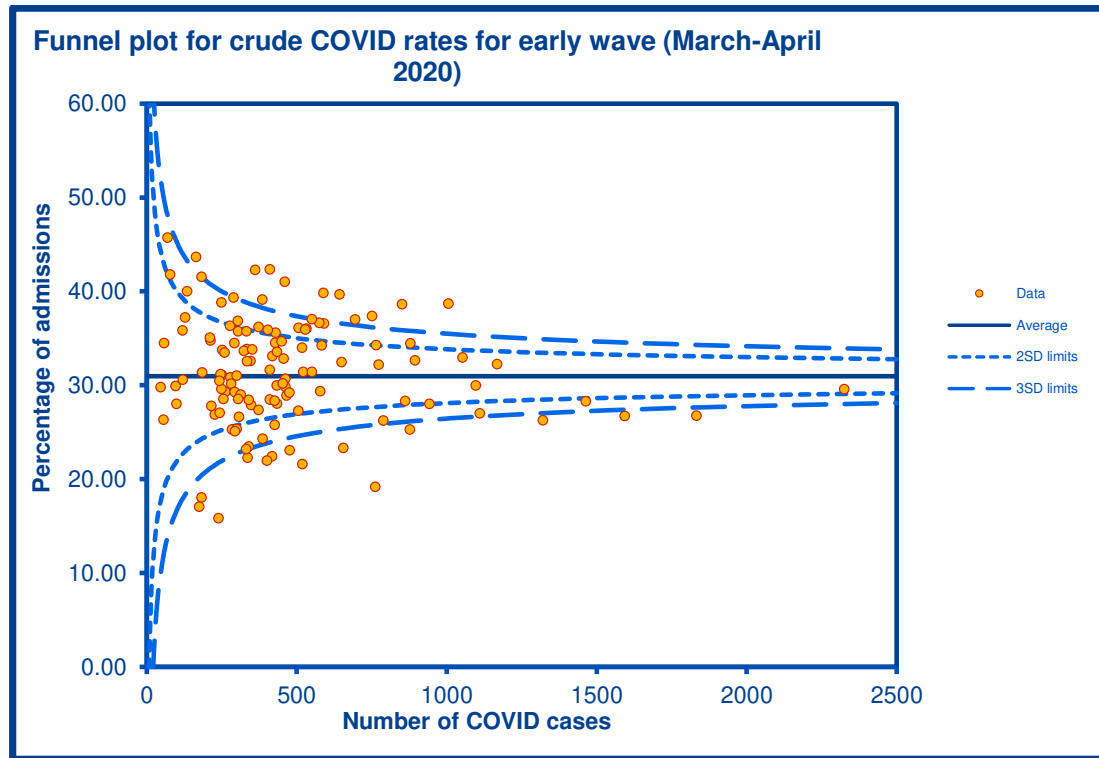


Figure A3. Funnel plot for the crude COVID-19 mortality rates for the late period (May to July 2020)

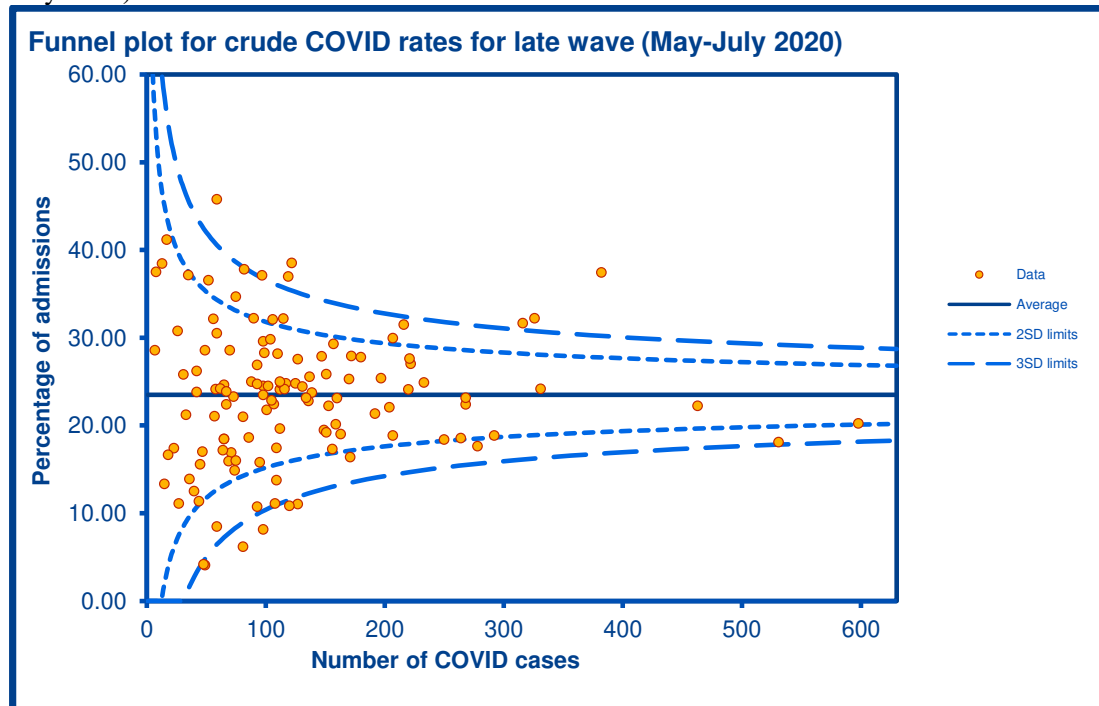


Figure A4. Funnel plot for the adjusted COVID-19 standardised mortality ratio for the early period (March to April 2020)

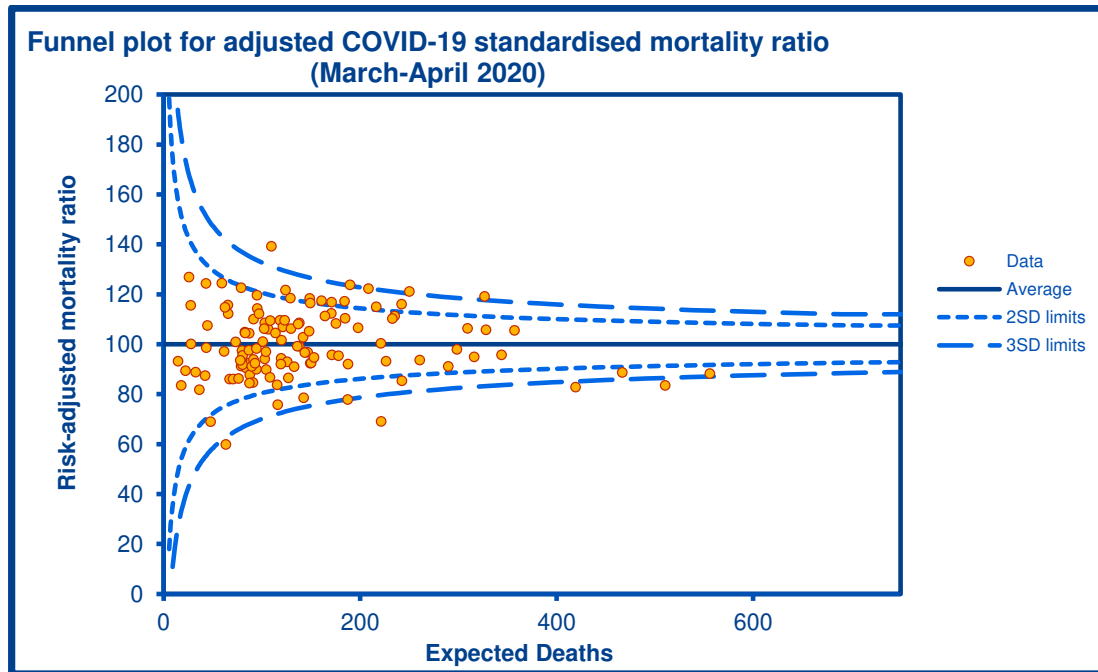
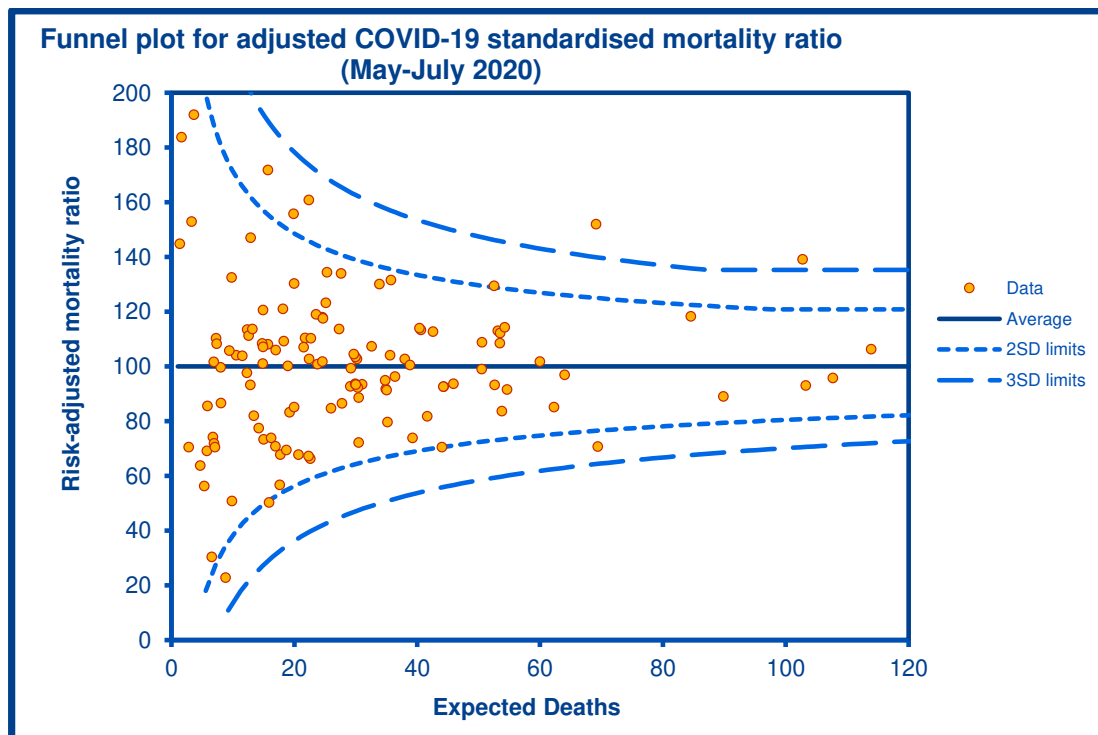


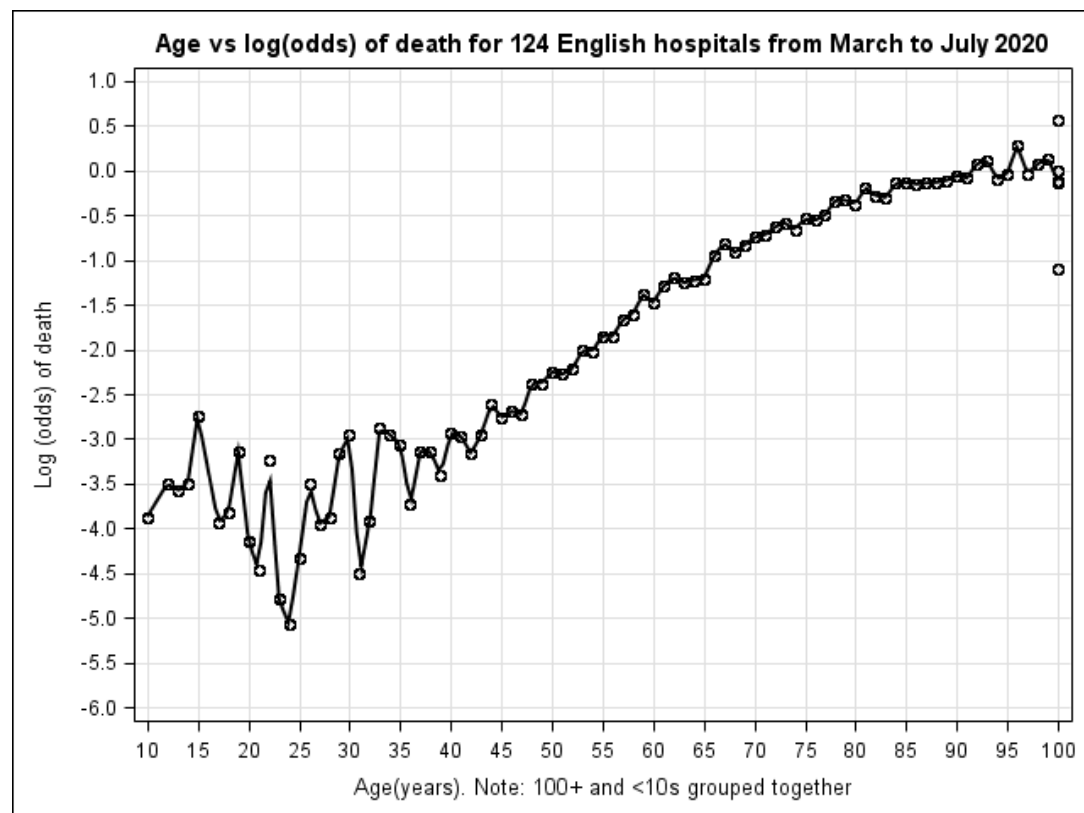
Figure A5. Funnel plot for the adjusted COVID-19 standardised mortality ratio for the late period (May to July 2020)



### Choosing how to model the hospital-level variables

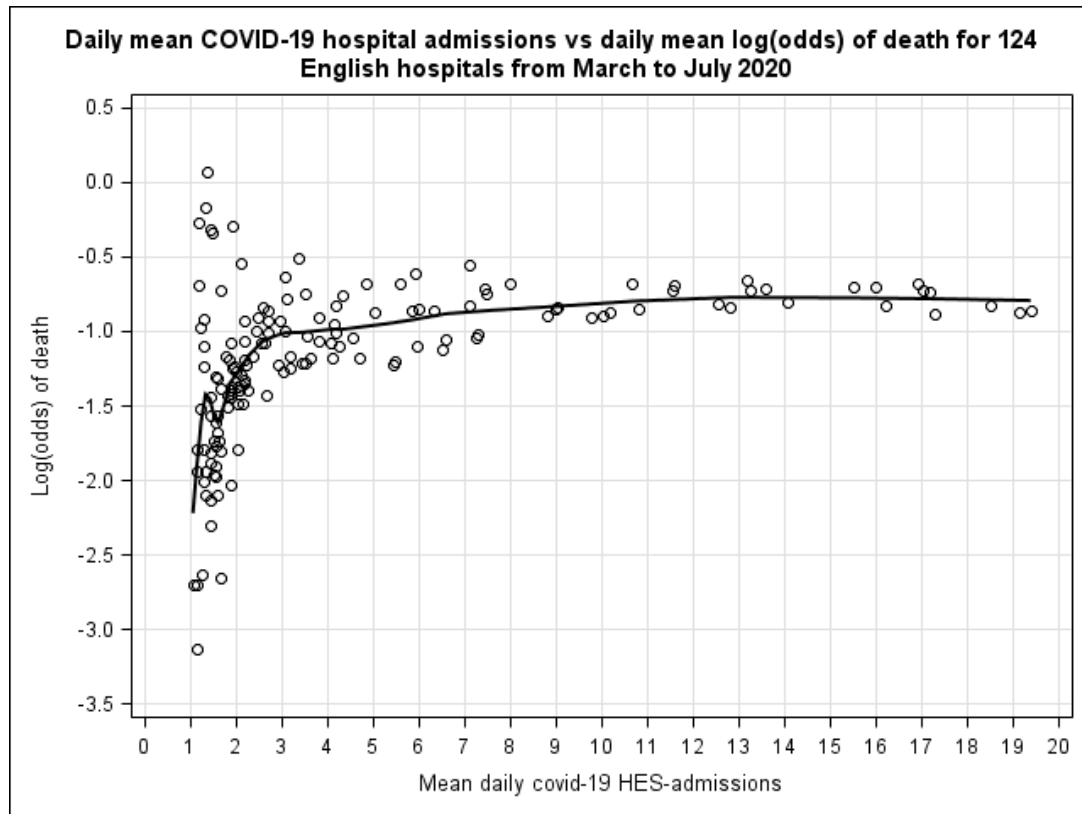
Continuous variables were plotted against the outcome to check for linearity and applied linear splines with 1 knot for each as justified below. In the final model, where the odds ratios were not different from 1 to two decimal places and where  $p > 0.05$ , the spline was replaced for the affected variables by a simple linear term.

Figure A6. Locally weighted smoothing (LOESS) plot of age against the log(odds) of death for 124 English hospitals from March to July 2020



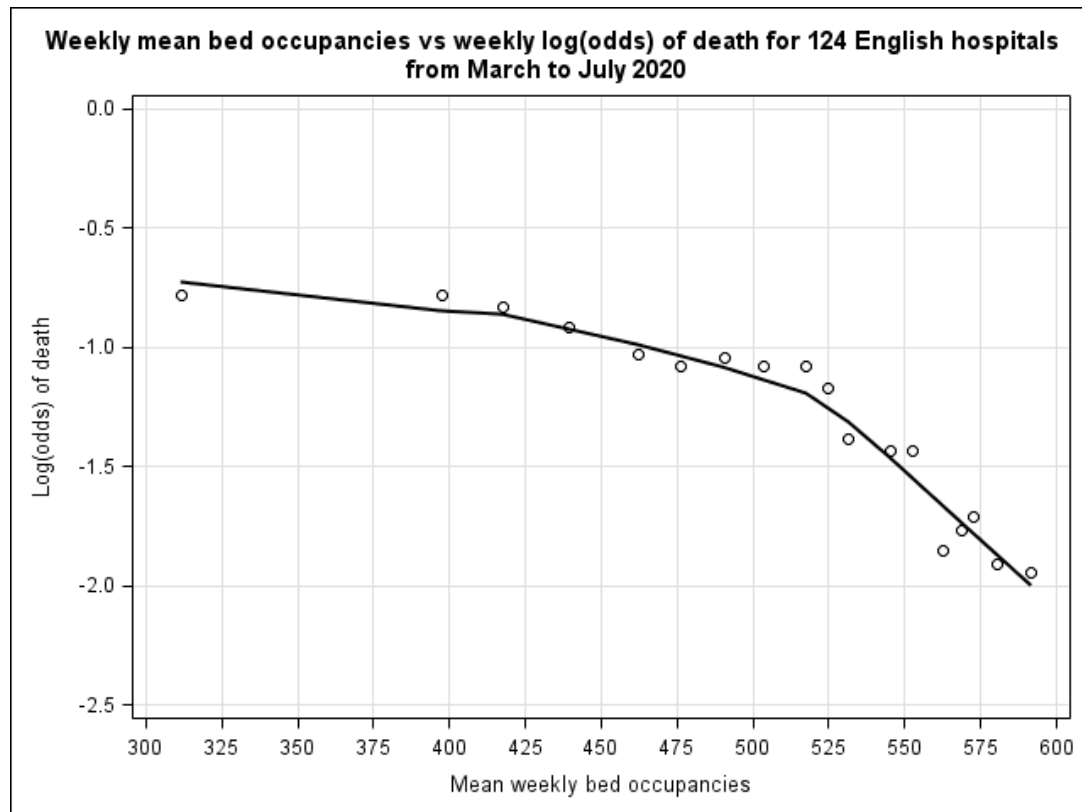
1 knot applied at 45 years

Figure A7. Locally weighted smoothing (LOESS) plot of daily mean COVID-19 hospital admissions against the daily mean log(odds) of death for 124 English hospitals from March to July 2020



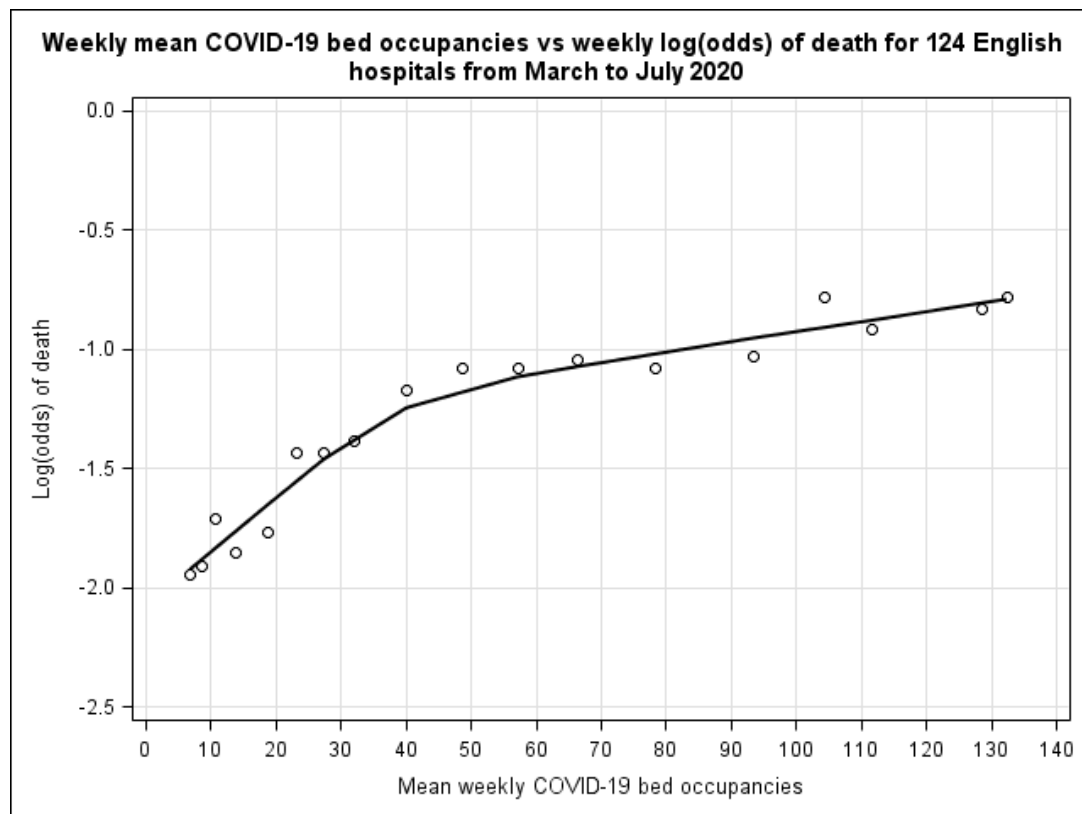
1 knot applied at 4 admissions

Figure A8. Locally weighted smoothing (LOESS) plot of weekly mean bed occupancies against the weekly log(odds) of death for 124 English hospitals from March to July 2020



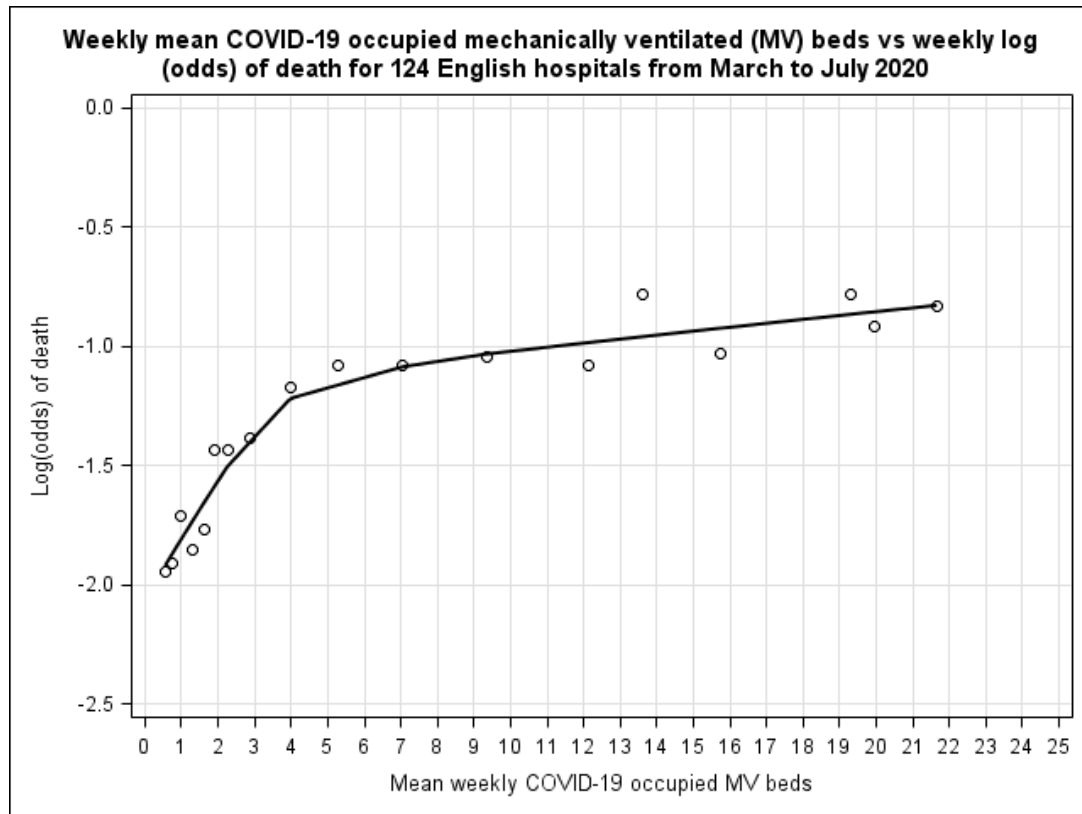
1 knot applied at 420 – tried 420 and 520 but 420 alone had lower AIC. The 420 AIC was lower than the knot at 520 alone.

Figure A9. Locally weighted smoothing (LOESS) plot of weekly mean COVID-19 bed occupancies against the weekly log(odds) of death for 124 English hospitals from March to July 2020



1 knot applied at 40

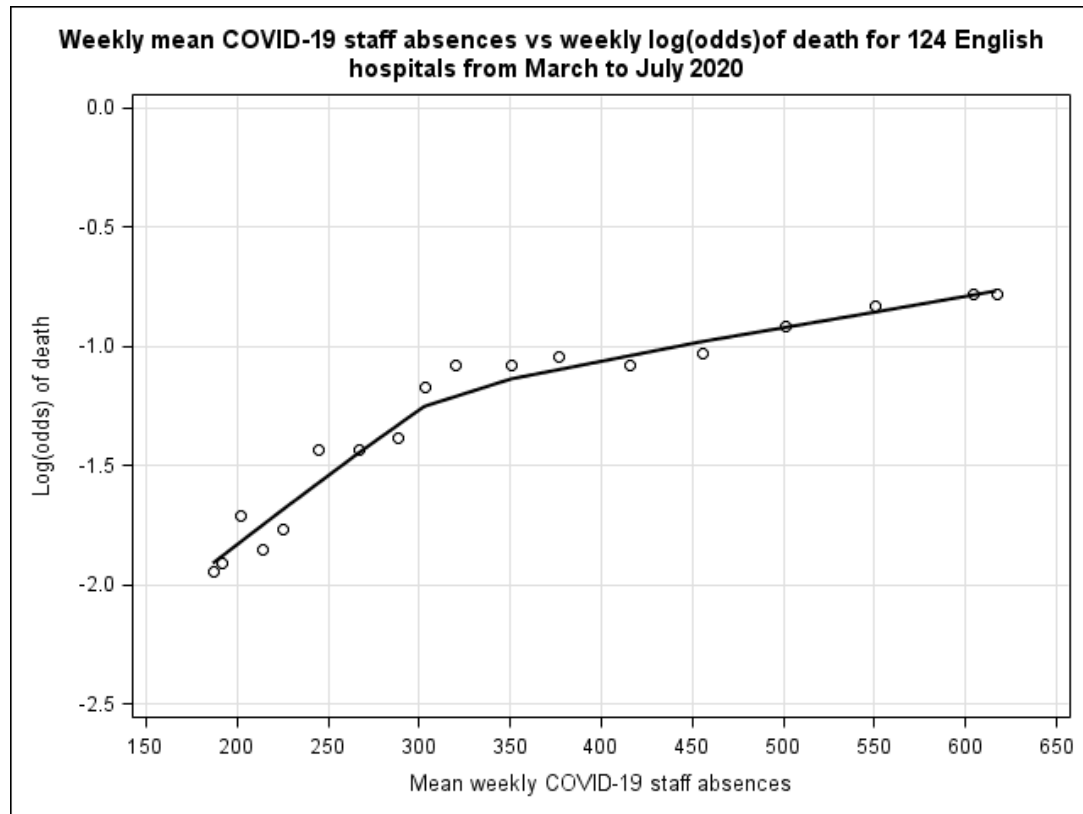
Figure A10. Locally weighted smoothing (LOESS) plot of weekly mean COVID-19 occupied mechanically ventilated beds against the weekly log(odds) of death for 124 English hospitals from March to July 2020



1 knot applied at 4



Figure A11. Locally weighted smoothing (LOESS) plot of weekly mean COVID-19 staff absences against the weekly log(odds) of death for 124 English hospitals from March to July 2020



1 knot applied at 300

Figure A12. Calibration plot for the early period multi-level model (March, April 2020)

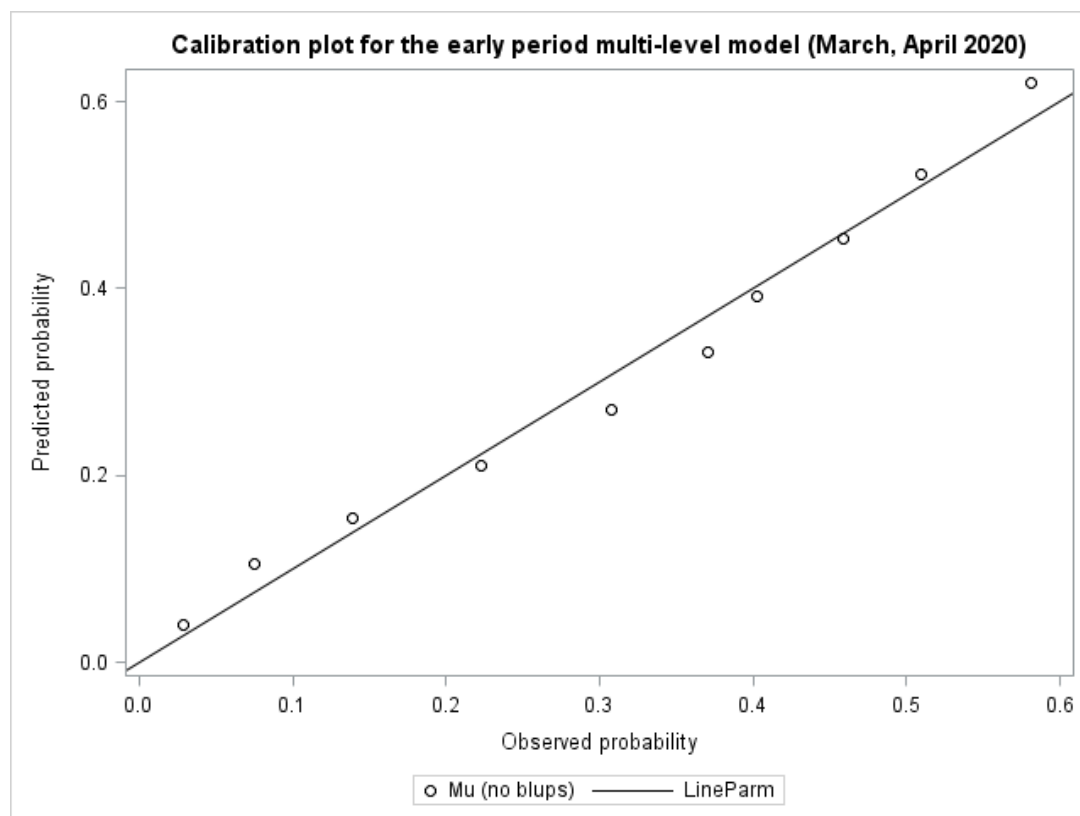


Figure A13. Calibration plot for the late period multi-level model (May, June and July 2020)

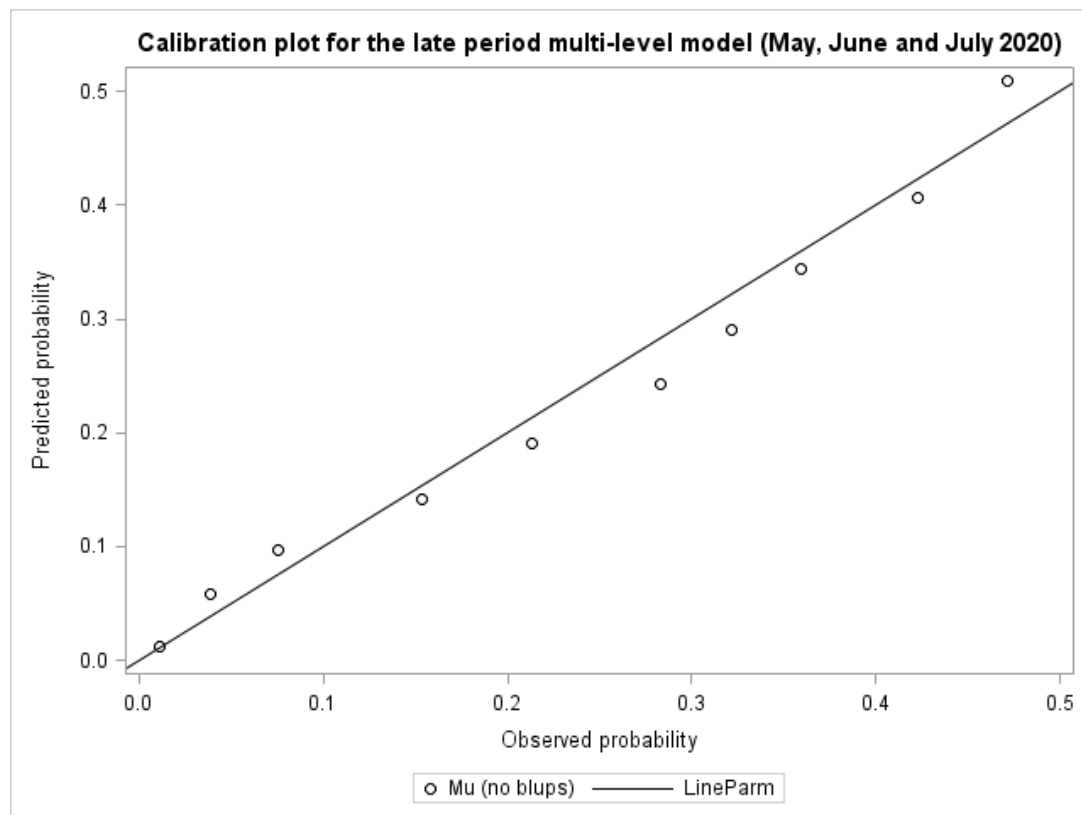


Table A1: Two-level logistic regression model results for in-hospital mortality for COVID-19 admissions for April 2020 only (Sensitivity analysis).

Feature	Value	April admissions only (N=40,069)	
		OR (95% CI)	P value
Age: OR per year	< 45 years	1.08 (1.07 to 1.10)	<0.0001
	45+ years	1.05 (1.03 to 1.07)	<0.0001
Gender	Male	1.39 (1.32 to 1.46)	<0.0001
	Female	1	
Ethnic group	Black or Black British	1.12 (0.99 to 1.26)	0.0623
	Asian or Asian British	1.23 (1.12 to 1.36)	<0.0001
	White	1	
	Other inc Mixed	1.05 (0.93 to 1.19)	0.4336
	Unknown	1.14 (1.05 to 1.23)	0.0016
Deprivation quintile	1 (least deprived)	1	
	2	1.06 (0.98 to 1.15)	0.1683
	3	1.08 (1.00 to 1.17)	0.0583
	4	1.14 (1.05 to 1.23)	0.0019
	5	1.10 (1.01 to 1.19)	0.0236
	6 (unknown)	0.68 (0.44 to 1.05)	0.0805
Method of admission	Emergency	1	
	Non-emergency	0.66 (0.51 to 0.86)	0.0024
Admission source	Home	1	
	Transfer from acute hospital	1.73 (1.23 to 2.41)	0.0014
	Transfer from non-acute hospital	1.43 (0.84 to 2.42)	0.1850
	Transfer from unknown hospital	1.00 (0.88 to 1.13)	0.9946
	Other / unknown	1.24 (1.10 to 1.39)	0.0004
Emergency admissions in previous 12 months	0	1	
	1	1.14 (1.07 to 1.21)	<0.0001
	2	1.15 (1.06 to 1.24)	0.0006
	3+	1.11 (1.03 to 1.20)	0.0045
Comorbidity	Diabetes	1.18 (1.12 to 1.24)	<0.0001
	Hypertension	0.95 (0.90 to 1.00)	0.0386
	Coronary heart disease	1.39 (1.30 to 1.49)	<0.0001
	COPD	1.06 (1.00 to 1.12)	0.0375
	Obesity	1.50 (1.37 to 1.65)	<0.0001
	Cancer	1.48 (1.35 to 1.62)	<0.0001
	Renal disease	1.25 (1.17 to 1.32)	<0.0001
	Dementia	1.48 (1.37 to 1.59)	<0.0001
COVID19 daily admissions	< 4 admissions	1.05 (0.97 to 1.14)	0.2408
	4+ admissions	1.0007 (0.927 to 1.095)	0.3191
Bed occupancy	Per 10 extra occupancies	0.998 (0.9966 to 0.9995)	0.0076
COVID19 bed occupancy	Per 10 extra occupancies	1.006 (0.9994 to 1.012)	0.0784
COVID19 MV bed occupancy	<4 beds	1.03 (0.98 to 1.07)	0.2231
	4+ beds	0.997 (0.957 to 1.039)	0.1766

COVID19 related staff absences	Per 10 extra occupancies	0.9996 (0.9985 to 1.001)	0.4556
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Table A2: Overall p-value for significance for all covariates in the early and late period two-level models

Feature	Overall p-values	
	Early period (March, April)	Late period (May, June, July)
Age		
<45 years	<0.0001*	<0.0001*
45+ years	0.0002*	0.0026*
Gender	<0.0001*	<0.0001*
Ethnic group	<0.0001*	0.2661
Deprivation quintile	0.0056*	0.0249*
Method of admission	0.1486	0.0045*
Admission source	<0.0001*	0.0183*
Emergency admissions in previous 12 months	<0.0001*	0.0800
Admission month	<0.0001*	0.0003*
Diabetes	<0.0001*	0.0795
Hypertension	0.0128*	<0.0001*
Coronary heart disease	<0.0001*	<0.0001*
COPD	0.1077	0.0232*
Obesity	<0.0001*	0.3631
Cancer	<0.0001*	<0.0001*
Renal disease	<0.0001*	<0.0001*
Dementia	<0.0001*	<0.0001*
COVID19 daily admissions		
<4 admissions	0.0873	0.0087*
4+ admissions	0.0506	0.0876
Bed occupancy	0.1443	0.0513
COVID19 bed occupancy	0.0900	0.9081
COVID19 MV bed occupancy		
<4 beds	0.9122	0.2251
4+ beds	0.9401	0.1217
COVID19 related staff absences	0.5020	0.5463

\*statistically significant