Modelling impact of pandemic influenza: Intensive Care Unit Requirements

December 2006

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1 Summary

- The figures shown in this report are estimates of the daily Intensive Care Unit (ICU) requirements in the event of an influenza pandemic. These estimates are based on predictions from the Health Protection Agency (HPA) empirical model.

- It is assumed that a 15-week single wave pandemic will involve a 25% Clinical Attack Rate (CAR) and that 0.55% of cases will require hospitalisation. Consideration is given to a range of Intensive Care Unit (ICU) admissions (5%, 15%, 25%) as a proportion of overall hospitalisations.

- Adopting an ICU rate of 15% of hospitalised cases, daily ICU bed requirements are considered, assuming varying length of ICU stay ranging from 2-10 days.

- Daily numbers of ventilators in use are considered over a range of ventilation requirements (25% -100% of ICU patients) and length of ICU stay (2 – 10 days) assuming that 15% of influenza-related hospitalisations require ICU care.

- A range of estimates is produced, depending on which assumptions are adopted. Assuming that 15% of influenza-related hospitalisations require critical care, new ICU admissions per day peak at 33 during week 6.

- Assuming that 15% of influenza-related hospitalisations require critical care, the peak number of ICU beds required nationally ranges from 64 (assuming 2 days length of stay) to 284 (10 days length of stay).

- The peak number of ventilators required per day ranges from 16 (assuming 25% of ICU patients require ventilation for a 2 day stay) to 284 (assuming 100% of ICU patients require ventilation for a 10 day stay).

- It is important to consider these estimates alongside the ICU resources available in Ireland in a pandemic situation.

- It is important to remember that all figures in this report are derived from a hospitalisation rate of 0.55%. This is the minimum rate that can be expected and therefore could be an underestimate of the true pandemic hospitalisation rate. Estimated daily hospitalisations based on a CAR of 50% and hospitalisation rate of 3.7% (a worst case scenario) are given in Appendix II.

2 Introduction

The report presented to the Pandemic Influenza Expert Group in January 2006 outlined three models used to estimate the impact of pandemic influenza in Ireland.([1]) The Health Protection Agency (HPA) empirical model has been adopted for planning purposes and provides estimates of weekly hospitalisations based on a 25% CAR and hospitalisation rate of 0.55% of cases.([1-3])

It is important to consider the ICU service requirements in the event of a pandemic. This report provides weekly and daily estimates of the number of ICU beds and ventilators required during a pandemic. The estimates provided are derived from applying various rates of ICU admission and ventilation to the weekly hospitalisation figures generated from the HPA empirical model.([1]) Daily hospitalisations have been approximated from the weekly totals suggested by the HPA model and used to derive daily ICU requirements using various assumptions relating to length of ICU stay.

The figures in this document have been derived based on the HPA assumption that the pandemic situation lasts for 15 weeks. It is assumed that the Clinical Attack Rate (CAR) is 25% and that 0.55% of clinical cases will be hospitalised[1].

[1] All calculations in this report based on the preliminary results of the 2006 census which indicated a total Irish population of 4,234,925

3 Weekly ICU admissions and ventilation requirements

Meltzer estimates that 33% of influenza patients hospitalised in the US during a pandemic will require a stay in the ICU.([4]) Other papers have applied different ICU rates; ranging from 5% to 25% of influenza-related hospitalisations. ([5;6])Various ICU admission rates (5%, 10%, 25%) have been applied to the weekly pandemic hospitalisations in Ireland (as predicted by the HPA empirical model) to produce estimates of the weekly ICU admissions.

After considering the number of ICU admissions in a week, different ventilation rates (25%, 50%, 75%) were used to derive estimated ventilation requirements. This ventilation rate range was also used in an Australian and New Zealand Intensive Care Society (ANZICS) paper to estimate ventilation requirements and is based on ventilation rates for community-acquired pneumonia.([6])

3.1 Assuming 5% of influenza-related hospitalisations require an ICU stay

Week No	Hospitalisations	New admissions to ICU	Number requiring ventilation		
			25%	50%	75%
1	8	0	0	0	0
2	12	1	0	0	0
3	48	2	1	1	2
4	182	9	2	5	7
5	614	31	8	15	23
6	1,255	63	16	31	47
7	1,232	62	15	31	46
8	831	42	10	21	31
9	566	28	7	14	21
10	439	22	5	11	16
11	305	15	4	8	11
12	152	8	2	4	6
13	91	5	1	2	3
14	50	3	1	1	2
15	38	2	0	1	1
	5,823				

Table 1: Weekly ICU admissions and ventilation requirements assuming 5% critical care rate within hospitalised patients and varying ventilation rate from 25% to 75%

3.2 Assuming 15% of influenza-related hospitalisations require an ICU stay

Week No	Hospitalisations	New admissions to ICU	Number requiring ventilation 25%	50%	75%
1	8	1	0	1	1
2	12	2	0	1	1
3	48	7	2	4	5
4	182	27	7	14	20
5	614	92	23	46	69
6	1,255	188	47	94	141
7	1,232	185	46	92	139
8	831	125	31	62	93
9	566	85	21	42	64
10	439	66	16	33	49
11	305	46	11	23	34
12	152	23	6	11	17
13	91	14	3	7	10
14	50	8	2	4	6
15	38	6	1	3	4
	5,823				

Table 2: Weekly ICU admissions and ventilation requirements assuming 15% critical care rate within hospitalised patients and varying ventilation rate from 25% to 75%

3.3 Assuming 25% of influenza-related hospitalisations require an ICU stay

Week No	Hospitalisations	New admissions to ICU	Number requiring ventilation 25%	50%	75%
1	8	2	1	1	2
2	12	3	1	1	2
3	48	12	3	6	9
4	182	45	11	23	34
5	614	154	38	77	115
6	1,255	314	78	157	235
7	1,232	308	77	154	231
8	831	208	52	104	156
9	566	141	35	71	106
10	439	110	27	55	82
11	305	76	19	38	57
12	152	38	9	19	28
13	91	23	6	11	17
14	50	13	3	6	9
15	38	10	2	5	7
	5,823				

Table 3: Weekly ICU admissions and ventilation requirements assuming 25% critical care rate within hospitalised patients and varying ventilation rate from 25% to 75%

4 Daily Hospitalisations

The HPA model predicts weekly total influenza-related hospitalisations. Daily hospitalisations are useful from a service planning perspective.

Estimates of the number of influenza-related hospitalisations per day (Table 4, Figure 1) were obtained from the HPA model weekly totals using 2 constraints:

- Daily hospitalisations for each 7-day period sum to the weekly total
- The number hospitalised per day is non-decreasing until the last day of week 6 and non-increasing from the first day of week 7.

Week	Hospitalisations	Hospitalisations by Day						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	8	1	1	1	1	1	1	2
2	12*	2	2	2	2	2	2	2
3	48	3	4	6	7	8	9	11
4	182*	14	18	22	26	30	34	37
5	614*	50	63	75	88	100	113	126
6	1255	139	152	166	179	193	206	220
7	1232	203	194	185	176	167	158	149
8	831*	139	133	126	119	112	105	98
9	566	91	88	84	81	77	74	71
10	439	67	66	64	63	61	60	58
11	305	57	52	48	44	39	35	30
12	152	26	24	23	22	20	19	18
13	91	16	15	14	13	12	11	10
14	50	8	8	8	7	7	6	6
15	38*	5	5	5	5	5	5	5

Table 4: Estimated daily hospitalisations generated from the HPA Model weekly totals, based on 25% CAR and 0.55% hospitalisation rate among clinical cases

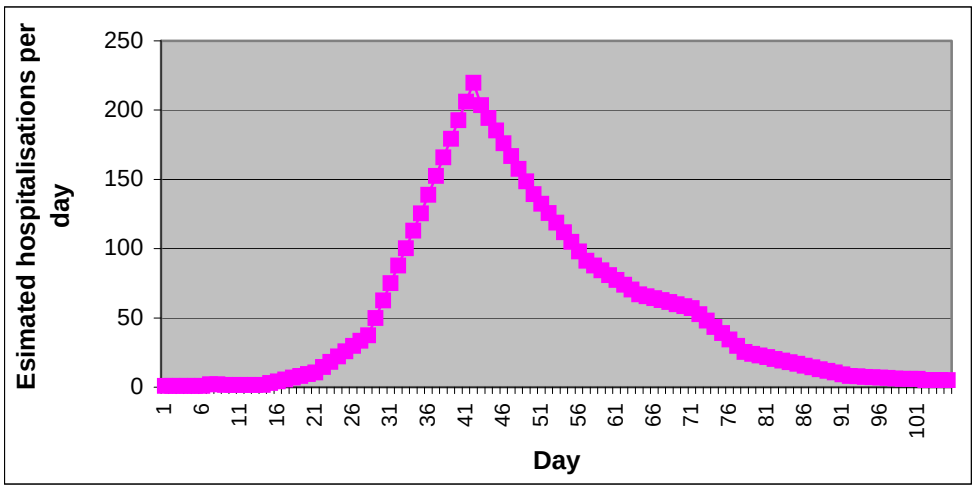

Figure 1: Estimated daily hospitalisations (generated from HPA Model) based on 25% CAR and 0.55% hospitalisation rate among clinical cases

* These rows do not sum to the exact weekly total due to rounding effects

5 Daily ICU and ventilation requirements

5.1 Daily ICU admissions

Assuming that 15% of influenza-related hospitalisations require critical care, daily admissions to ICU are estimated as♣:

Week	ICU admissions	ICU admissions by Day						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	1	1	1	1	2
4	27	2	3	3	4	4	5	6
5	92	8	9	11	13	15	17	19
6	188	21	23	25	27	29	31	33
7	185	31	29	28	26	25	24	22
8	125	21	20	19	18	17	16	15
9	85	14	13	13	12	12	11	11
10	66	10	10	10	9	9	9	9
11	46	9	8	7	7	6	5	5
12	23	4	4	3	3	3	3	3
13	14	2	2	2	2	2	2	1
14	8	1	1	1	1	1	1	1
15	6	1	1	1	1	1	1	1

Table 5: Daily ICU admissions derived from HPA model assuming that 15% of daily hospitalisations require ICU facilities

5.2 Daily ICU bed requirements

Based on the assumptions made in the previous sections (25% CAR over a 15 week period, 0.55% of cases hospitalised) and adopting the idea that 15% of hospitalised patients require a stay in ICU, the daily totals of ICU beds required can be predicted. It is likely that a patient's stay in ICU will be longer than one day.([7;8]) A rolling total is needed in order to estimate the total number of ICU beds required per day.

Tables 6,7 and 8 show the estimated ICU bed requirements assuming that 15% of hospital admissions require a stay in ICU and that the length of ICU stay is 2, 7 or 10 days.

♣ICU admissions per day calculated as 15% of estimated daily hospitalisations (Table 4) therefore may not sum to exact weekly totals due to rounding effects

5.2.1 Length of stay in ICU – 2 days

Week	ICU admissions	No. ICU beds required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	2	2	2	3
4	27	4	5	6	7	8	9	11
5	92	14	17	20	24	28	32	36
6	188	40	44	48	52	56	60	64
7	185	64	60	57	54	51	49	46
8	125	43	41	39	37	35	33	31
9	85	29	27	26	25	24	23	22
10	66	21	20	20	19	18	18	18
11	46	18	17	15	14	13	11	10
12	23	9	8	7	6	6	6	6
13	14	5	4	4	4	4	4	3
14	8	2	2	2	2	2	2	2
15	6	2	2	2	2	2	2	2
16	0	1	0	0	0	0	0	0

Table 6: Daily totals of ICU beds required derived from HPA model assuming that 15% of daily hospitalisations require a 2 day stay in ICU

5.2.2 Length of stay in ICU – 7 days

Week	ICU admissions	No. ICU beds in use						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	3	4	5	7
4	27	9	11	13	16	19	23	27
5	92	33	39	47	56	67	79	92
6	188	105	119	133	147	161	175	189
7	185	199	205	208	207	203	196	185
8	125	175	166	157	149	141	133	126
9	85	119	112	106	100	95	90	86
10	66	82	79	76	73	70	68	66
11	46	65	63	60	58	55	51	47
12	23	42	38	34	30	27	25	23
13	14	21	19	18	17	16	15	13
14	8	12	11	10	9	8	7	7
15	6	7	7	7	7	7	7	7
16	0	6	5	4	3	2	1	0

Table 7: Daily totals of ICU beds required derived from HPA model assuming that 15% of daily hospitalisations require a 7 day stay in ICU

5.2.3 Length of stay in ICU – 10 days

Week	ICU admissions	No. ICU beds in use						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	3	4	5	7
4	27	9	12	15	19	22	26	31
5	92	38	46	55	66	78	92	107
6	188	124	142	161	180	200	220	240
7	185	256	268	277	282	284	283	278
8	125	270	259	245	232	220	208	197
9	85	186	175	166	157	149	141	134
10	66	127	121	116	111	107	103	100
11	46	97	94	90	87	83	78	74
12	23	69	64	58	52	47	43	39
13	14	35	32	29	27	25	24	22
14	8	20	18	16	15	14	13	12
15	6	11	10	10	10	10	10	10
16	0	9	8	7	6	5	4	3

Table 8: Daily totals of ICU beds required derived from HPA model assuming that 15% of daily hospitalisations require a 10 day stay in ICU

5.3 Daily ventilation requirements

Published literature assumes a range of ventilation requirements. The February 2005 HPA plan [5]assumed that 100% of ICU patients would require ventilation and that ICU admissions would make up 5% of influenza-related hospitalisations.[8]The HPA plan ICU rate of 5% of all admissions is lower than 15% rate used in this report.

Meltzer [4] assumed that 50% of ICU patients would require ventilation. The ANZICS paper considered ventilation rates of 25%, 50% and 75% within ICU patients.[6]

A range of ventilation requirements (25%, 50%, 75%, 100% of ICU patients) and ICU length of stay (2, 7, 10 days) have been considered in the figures below. A detailed breakdown of the daily totals depicted in Figures 2, 3 and 4 can be seen in Appendix I.

5.3.1 Length of stay in ICU - 2 days

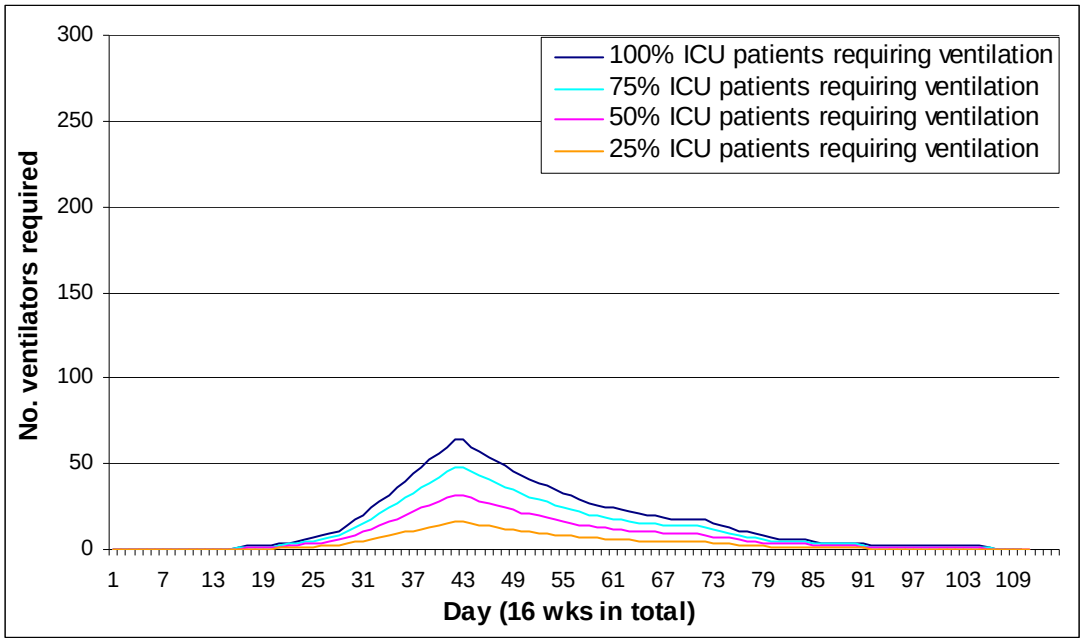

Figure 2: Daily ventilation requirements based on a range of ventilation rates and assuming that 15% of hospitalised patients enter ICU for a 2 day stay

5.3.2 Length of stay in ICU - 7 days

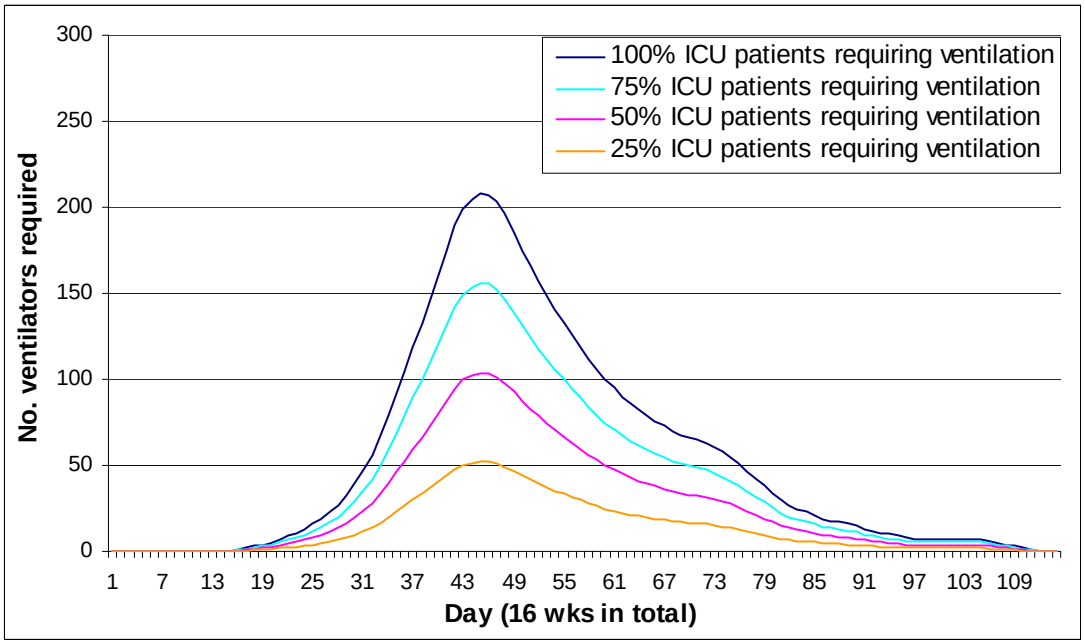

Figure 3: Daily ventilation requirements based on a range of ventilation rates and assuming that 15% of hospitalised patients enter ICU for a 7 day stay

5.3.3 Length of stay in ICU - 10 days

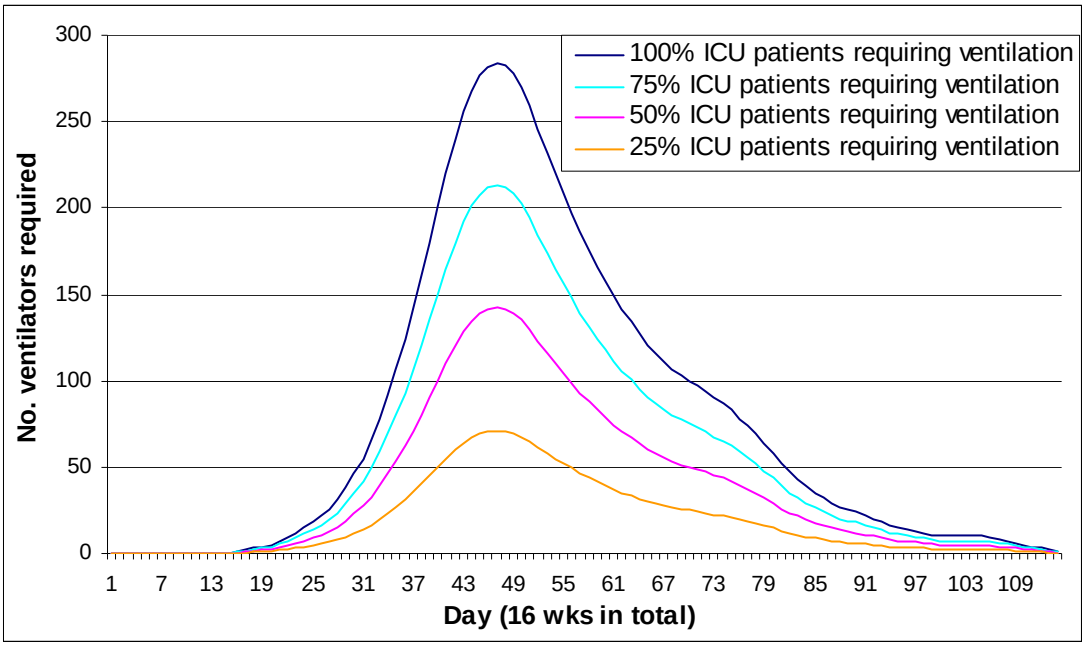

Figure 4: Daily ventilation requirements based on varying ventilation rates and assuming that 15% of hospitalised patients enter ICU for a 10 day stay

6 References

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7. Oliveira EC, Marik PE, Colice G. Influenza Pneumonia: A descriptive study. Chest 2001; 119(6):1717-1723.

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This report was prepared by Kate Hunter, Dr Derval Igoe and Dr Darina O'Flanagan, HPSC.

7 Appendix I – numbers depicted in Figures 2, 3 and 4

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	0	1	1	1	1	1
4	27	1	1	2	2	2	2	3
5	92	4	4	5	6	7	8	9
6	188	10	11	12	13	14	15	16
7	185	16	15	14	14	13	12	12
8	125	11	10	10	9	9	8	8
9	85	7	7	7	6	6	6	6
10	66	5	5	5	5	5	5	5
11	46	5	4	4	4	3	3	3
12	23	2	2	2	2	2	2	2
13	14	1	1	1	1	1	1	1
14	8	1	1	1	1	1	1	1
15	6	1	1	1	1	1	1	1
16	0	0	0	0	0	0	0	0

Table A1: Daily ventilation requirements assuming 2-day stay in ICU, 25% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	1	1	1	1	2
4	27	2	3	3	4	4	5	6
5	92	7	9	10	12	14	16	18
6	188	20	22	24	26	28	30	32
7	185	32	30	29	27	26	25	23
8	125	22	21	20	19	18	17	16
9	85	15	14	13	13	12	12	11
10	66	11	10	10	10	9	9	9
11	46	9	9	8	7	7	6	5
12	23	5	4	4	3	3	3	3
13	14	3	2	2	2	2	2	2
14	8	1	1	1	1	1	1	1
15	6	1	1	1	1	1	1	1
16	0	1	0	0	0	0	0	0

Table A2: Daily ventilation requirements assuming 2 day stay in ICU, 50% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	2	2	2	2
4	27	3	4	5	5	6	7	8
5	92	11	13	15	18	21	24	27
6	188	30	33	36	39	42	45	48
7	185	48	45	43	41	38	37	35
8	125	32	31	29	28	26	25	23
9	85	22	20	20	19	18	17	17
10	66	16	15	15	14	14	14	14
11	46	14	13	11	11	10	8	8
12	23	7	6	5	5	5	5	5
13	14	4	3	3	3	3	3	2
14	8	2	2	2	2	2	2	2
15	6	2	2	2	2	2	2	2
16	0	1	0	0	0	0	0	0

Table A3: Daily ventilation requirements assuming 2 day stay in ICU, 75% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	0	1	1	1	1	2
4	27	2	3	3	4	5	6	7
5	92	8	10	12	14	17	20	23
6	188	26	30	33	37	40	44	47
7	185	50	51	52	52	51	49	46
8	125	44	42	39	37	35	33	32
9	85	30	28	27	25	24	23	22
10	66	21	20	19	18	18	17	17
11	46	16	16	15	15	14	13	12
12	23	11	10	9	8	7	6	6
13	14	5	5	5	4	4	4	3
14	8	3	3	3	2	2	2	2
15	6	2	2	2	2	2	2	2
16	0	2	1	1	1	1	0	0

Table A4: Daily ventilation requirements assuming 7 day stay in ICU, 25% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	1	2	2	3	4
4	27	5	6	7	8	10	12	14
5	92	17	20	24	28	34	40	46
6	188	53	60	67	74	81	88	95
7	185	100	103	104	104	102	98	93
8	125	88	83	79	75	71	67	63
9	85	60	56	53	50	48	45	43
10	66	41	40	38	37	35	34	33
11	46	33	32	30	29	28	26	24
12	23	21	19	17	15	14	13	12
13	14	11	10	9	9	8	8	7
14	8	6	6	5	5	4	4	4
15	6	4	4	4	4	4	4	4
16	0	3	3	2	2	1	1	0

Table A5: Daily ventilation requirements assuming 7 day stay in ICU, 50% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	2	3	4	5
4	27	7	8	10	12	14	17	20
5	92	25	29	35	42	50	59	69
6	188	79	89	100	110	121	131	142
7	185	149	154	156	155	152	147	139
8	125	131	125	118	112	106	100	95
9	85	89	84	80	75	71	68	65
10	66	62	59	57	55	53	51	50
11	46	49	47	45	44	41	38	35
12	23	32	29	26	23	20	19	17
13	14	16	14	14	13	12	11	10
14	8	9	8	8	7	6	5	5
15	6	5	5	5	5	5	5	5
16	0	5	4	3	2	2	1	0

Table A6: Daily ventilation requirements assuming 7 day stay in ICU, 75% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	0	1	1	1	1	2
4	27	2	3	4	5	6	7	8
5	92	10	12	14	17	20	23	27
6	188	31	36	40	45	50	55	60
7	185	64	67	69	71	71	71	70
8	125	68	65	61	58	55	52	49
9	85	47	44	42	39	37	35	34
10	66	32	30	29	28	27	26	25
11	46	24	24	23	22	21	20	19
12	23	17	16	15	13	12	11	10
13	14	9	8	7	7	6	6	6
14	8	5	5	4	4	4	3	3
15	6	3	3	3	3	3	3	3
16	0	2	2	2	2	1	1	1

Table A7: Daily ventilation requirements assuming 10 day stay in ICU, 25% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	1	2	2	3	4
4	27	5	6	8	10	11	13	16
5	92	19	23	28	33	39	46	54
6	188	62	71	81	90	100	110	120
7	185	128	134	139	141	142	142	139
8	125	135	130	123	116	110	104	99
9	85	93	88	83	79	75	71	67
10	66	64	61	58	56	54	52	50
11	46	49	47	45	44	42	39	37
12	23	35	32	29	26	24	22	20
13	14	18	16	15	14	13	12	11
14	8	10	9	8	8	7	7	6
15	6	6	5	5	5	5	5	5
16	0	5	4	4	3	3	2	2

Table A8: Daily ventilation requirements assuming 10 day stay in ICU, 50% ventilation rate

Week	New ICU admissions	No. ventilators required						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0	0
3	7	0	1	2	2	3	4	5
4	27	7	9	11	14	17	20	23
5	92	29	35	41	50	59	69	80
6	188	93	107	121	135	150	165	180
7	185	192	201	208	212	213	212	209
8	125	203	194	184	174	165	156	148
9	85	140	131	125	118	112	106	101
10	66	95	91	87	83	80	77	75
11	46	73	71	68	65	62	59	56
12	23	52	48	44	39	35	32	29
13	14	26	24	22	20	19	18	17
14	8	15	14	12	11	11	10	9
15	6	8	8	8	8	8	8	8
16	0	7	6	5	5	4	3	2

Table A9: Daily ventilation requirements assuming 10 day stay in ICU, 75% ventilation rate

8 Appendix II - Daily hospitalisations assuming 3.7% of cases are hospitalised

The weekly total hospitalisations in Table A10 are based on the assumption that there is a 50% CAR and that 3.7% of cases are hospitalised. Using the same constraints as described in section 4, daily estimates of hospitalisations have been produced and are displayed below.

Week	Hospitalisations	Hospitalisations by Day						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	113	10	11	14	16	18	21	23
2	160*	23	23	23	23	23	23	23
3	642*	40	57	74	92	109	126	143
4	2445	195	246	298	349	401	452	504
5	8266	673	842	1012	1181	1350	1519	1689
6	16886	2168	2250	2331	2412	2494	2575	2656
7	16579	2738	2615	2492	2368	2245	2122	1999
8	11181*	1876	1783	1690	1597	1504	1411	1319
9	7610*	1226	1180	1133	1087	1041	995	949
10	5910	903	883	864	844	825	805	786
11	4099	767	706	646	586	525	465	404
12	2040	344	327	309	291	274	256	239
13	1227	221	206	191	175	160	145	129
14	675	114	108	102	96	91	85	79
15	514*	73	73	73	73	73	73	73
	78,346							

Table A10: Estimated daily hospitalisations generated from the HPA Model weekly totals, based on 50% CAR and 3.7% hospitalisation rate among clinical cases

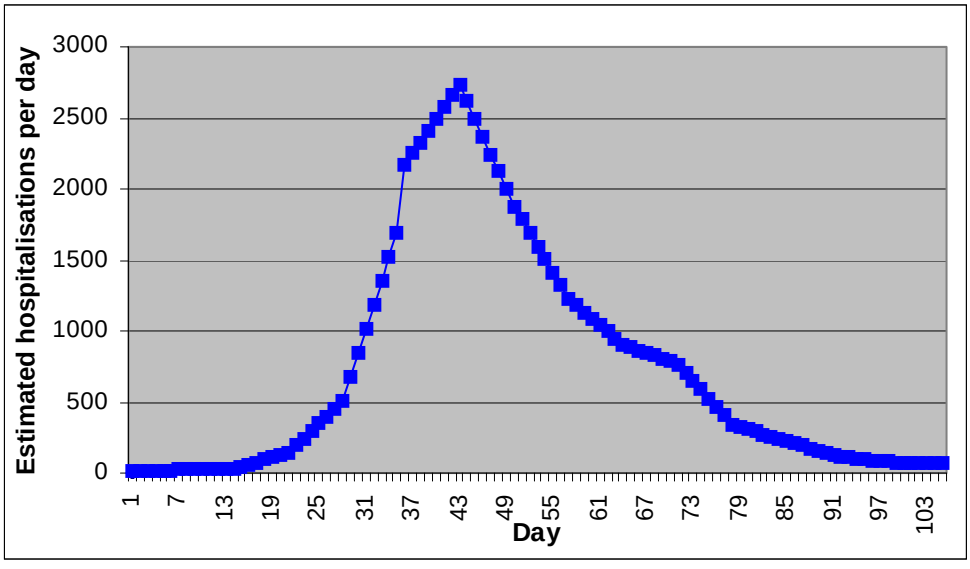

Figure A1: Estimated hospitalisations per day (HPA Model), based on 25% CAR and 3.7% hospitalisation rate among clinical cases

* These rows do not sum to the exact weekly total due to rounding effects