Considerations on occupational use of COVID-19 vaccines: Evaluating risks of infection and death from SARS-COV-2

PHE Immunisation Team

Key Findings

- Keyworkers represent a third of the total workforce in the UK.
- Close and frequent proximity to other individuals and prolonged exposure can increase risk of infection and onward transmission in occupational settings.
- Based on experience of the first wave, healthcare professionals (HCWs) have more frequent and closer contact with infected individuals compared to other professions and therefore have higher estimated infection rates.
- UK modelling of the expected mortality in HCWs, assuming around a 3-fold increased risk of infection, would support the current prioritisation strategy to offer vaccine to HCWs alongside those over 80 years of age. This model includes the additional advantage of potentially reducing secondary transmission to highly vulnerable patients.
- Although data on infection rates in other occupations are limited, UK case data has indicated a high risk among some other occupational groups during the first wave.
- Mortality data suggests a higher risk of death from COVID in some occupations, particularly in men; this includes those working in construction, taxi drivers and security guards. This most likely reflects a combination of moderate infection rates with a high proportion of that workforce having underlying clinical and demographic risk factors for severe disease.
- The highest numbers of deaths and the death rate amongst other occupational groups are in those aged 50 and above, who would be offered vaccine under the current age-based prioritisation strategy advised by JCVI.
- US models, without a transmission impact, also support the dominance of an age-based policy with vaccination of health care staff to a lower age than most other occupations. Prioritisation vaccination of other occupations to a younger age risks diverting vaccine from older people at higher risk.

Introduction

The Joint Committee on Vaccination and Immunisation (JCVI) is currently reviewing the evidence to prioritise use of a safe and effective COVID-19 vaccine(s) when it becomes available. The initial objective of the vaccine programme, as data on preventing transmission will be lacking and supplies may be constrained, is to minimise mortality and reduce the burden on the NHS. In the interim guidance, therefore, JCVI has prioritised the groups who are at highest risk of death, plus those who are at high risk of transmission to these 'vulnerable' individuals. This results in a strategy predominantly based on age and clinical co-morbidities alongside those staff working in the health and social care sectors. The latter advice arises from the modelled number of deaths and QALYs averted per vaccine dose being very close to figures for those aged 80 and over. This expected mortality arises from the documented very high incidence of infection in health care workers over the first wave, assumes an age-specific mortality in line with the rest of the population and allows for some indirect protection to the vulnerable client groups.

This paper considers and compares the risk of severe disease and death in health and social care workers for whom vaccine is being advised, with other occupational groups, and examines how that risk is modified by age. Whilst JCVI has already considered the groups/individuals who are at risk of severe disease with, or death as a result of SARS-CoV-2 infection based on their age or underlying clinical conditions, we also need to consider the characteristics of an occupation that would lead to increased risk of exposure, disease and death.

Between 2017 and 2019, 32.3 million people were employed in the UK workforce setting. 33% of the total work-force were classified as key-workers (McSweeney 2020). The largest number of named "key-workers" are those within health and social care sector (~2,916,000, 31% of total), table 1 (Bowers 2020), but other industries including education, utilities, food and transport contribute large numbers. Smaller numbers are contributed by other sectors such as public safety and security. Within this setting, ONS have stratified the working population by occupation and their proportional ethnicity and deprivation (Butt 2020).

Key worker occupation group	number of key workers
Health and social care	3276595
Education and childcare	2168876
Utilities and communication	1726847
Food and necessary goods	1473490
Transport	611742
Key public services	560433
Public safety and national security	539386
National and local governments	254728

Table 1 Number of keyworkers by occupation group, UK. Figure taken from the Office for National Statistics (Bowers 2020).

How does Occupation lead to Infection risk?

Occupational risk, defined by the probability of illness or injury (in this setting, specific to Sars-CoV-2) incurred within the workplace varies widely between keyworkers. For SaRS-CoV-2 this largely depends on the exposure to potentially infected individuals and so proximity to and frequency of contact are key determinants.

For all keyworkers, where working from home was not an option and prior to social distancing measures in the workplace being in place, their profession may mandate high frequency contact with multiple individuals, thus increasing their chances of acquiring infection. Amongst health and social care workers, a high incidence of infection likely reflects their exposure to infected individuals for a longer duration (McSweeney 2020). For those staff working in hospital settings in particular, exposure to the sickest individuals, who may have high viral loads (Miriam Mutambudzi) may also be relevant given that this correlates with the highest infectivity (Eric A. Meyerowitz, Rajesh T. Gandhi et al. 2020).

Other workplaces have also been implicated in high rates of transmission, although this is largely likely due to specific working conditions that facilitate transmission and the absence of infection control measures particularly during the first wave. For example, working in food processing plants has been linked to multiple outbreaks (Table 2), with this likely be due to a combination of close contact with other individuals in spatially constrained environments, with more voice projection due to background noise and certain atmospheric conditions that may favour viral spread (Lally 2020).

Table 2: Summary of workplace incidents in England, reported to PHE, weeks 27-41

Workplace type	Data week number															Grand Total
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	
Close Contact Services					1		1			3			3	3	2	13
Distributors and Transporters	1			1	1	3		4	2	8	8	4	15	18	19	84
First Responders				1	2			2		1	5	9	3	7	18	48
Manufacturers and packers (Food)	5	1		6	10	6	6	4	6	9	9	6	14	15	19	116
Manufacturers and packers (Non-Food)	8	4		7	5	8	7	7	5	9	8	17	38	33	38	194
Military sites											1	1	2	2	3	9
Office	2	2		1	4	7	5	2	6	7	20	20	35	45	36	192
Other	2	2		1	6	9	8	6	14	15	28	35	42	37	60	265
Primary producers		1		1								2			4	8
Restaurant and Caterers	1	2		2		2	1	1	2	1	7	5	11	6	12	53
Retailer	6	5	1	4	6	9	9	6	6	9	21	18	34	42	42	218
Warehouses	4	3		2	5	3	5	1	4	2	2	7	4	2	14	58
Not known	6	19	29	1									1	3		59
Grand Total	35	39	30	27	40	47	42	33	45	64	109	124	202	213	267	1317

Estimating Infection rates by Occupation

The Office for National Statistics has published data estimating the risk of viral exposure in different occupational groups. This was estimated from workers' own perception of their (1) proximity of contact to other individuals and (2) their risk of being exposed to a generic disease/infection (Table 2). Although this is largely based on subjective assessment undertaken prior to the COVID epidemic, this tool has been used to correlate with and then predict rates of SARS-CoV-2 infection in different occupational groups.

These UK estimates have shown that healthcare workers are more likely to experience close contact with other individuals and are likely to have increased exposure to disease compared to virtually all other occupational groups (Statistics 2020).

Occupations such as frontline healthcare workers, for example nurses and dental practitioners, involve close contact with a large number of individuals and also potentially being exposed to disease on a daily basis. There are some other occupations in which workers are in close contact with other people but are less frequently directly exposed to disease. Normally, workers in elementary occupations e.g. factory packers and hospitality roles, such as bar staff, chefs, and hairdressers are in close proximity to people but not exposed to disease (Table 1). Because of the nature of these roles requiring close contact with people, however, employees in these occupations may be more likely to come into contact with someone who has asymptomatic COVID-19. Unlike health care work, where contact may be preferentially with infected individuals, the risk in these other occupations will be largely driven by the extent of local circulation.

Workers in the education sector have lower exposure to disease than healthcare workers, but primary and nursery education teaching professionals, and special needs education professionals, do work in closer proximity with pupils and are therefore more likely to be exposed to disease than secondary or higher education teaching professionals.

ONS have also considered the other factors that have an impact on the likelihood that SARS-CoV-2 infection will result in severe COVID-19; the proportion of males/females in a particular occupation, the age of the employee and their ethnicity (Table 3). This varies considerably with approximately 44% of taxi drivers, 32% security guards and 28% medical and dental practitioners from BAME groups compared with only around 3% of police officers.

Occupation	Proximity to others	Exposure to disease	Total	F (%)	>55yrs (%)	BAME (%)
Medical practitioners	89.2	91.2	296,000	48.9	16.5	27.9
Nursing auxiliaries and assistants	90.0	87.0	338,000	81	22.2	18.5
Dental practitioners	97	90	41000	52.6	11.8	28.2
Nurses	86.0	91.5	669,000	88.5	21.3	19.4
Midwives	97.0	89.0	45,000	>95	16.5	11.3
Care workers and home carers	84.8	41.3	773,000	83.7	23	19.2
Physiotherapists	96.5	61.0	73,000	73.4	11.3	7.5
Higher education teaching professionals	50.7	11.1	178,000	46.4	25.8	9.9
Further education teaching professionals	77.0	23.7	127,000	57	28.1	9.6
Secondary education teaching professionals	70.0	17.0	395,000	62.4	12.3	8.1
Primary and nursery education teaching professionals	74.5	50.0	437,000	85.7	9.8	7
Police officers (sergeant and below)	77.0	62.8	153,000	32.7	4.3	3.6
Carpenters and joiners	80.0	9.0	221,000	1.3	18.1	3.2
Construction and building trades n.e.c.	50.0	4.0	252,000	3.6	23.4	5.5
Chefs	88.0	20.5	244,000	20.7	11.8	21.1
Hairdressers and barbers	89.0	32.8	166,000	86.3	12.2	8.9
Sales and retail assistants	68.0	9.5	1,048,000	66.2	16.4	13.3
Market and street traders and assistants	67.0	7.0	15,000	46	24.7	22.7
Food, drink and tobacco process operatives	55.8	8.2	130,000	39.8	16.9	14.7
Bus and coach drivers	73.8	43.3	118,000	8.9	40.9	19.4
Taxi and cab drivers and chauffeurs	75.8	27.4	231,000	3.6	30.7	44.1
Elementary construction occupations	67.6	13.7	158,000	2.3	15.8	5.2
Elementary process plant occupations	57.0	2.0	95,000	19	20.1	7.9
Cleaners and domestics	48.3	38.3	585,000	82	29.7	11.9
Security guards and related occupations	77.3	33.0	190,000	15.3	27.1	31.8
Sales and retail assistants	68.0	9.5	1,048,000	66.2	16.4	13.3
Elementary process plant occupations	57.0	2.0	95,000	19	20.1	7.9
Packers, bottlers, canners and fillers	70.0	5.0	131,000	49.2	16.3	18.4
Publicans and managers of licensed premises	49.0	4.0	40,000	45	13.6	4.5
Bar staff	79.0	4.0	204,000	49.5	5.5	4.9

Table 3. Selected list of professions with calculated exposure to disease and proximity measurements, the total numbers within the workforce, the percentage represented by famales, black and ethnic minority groups and also those greater than 55 years of age. Modified (Statistics 2020).

A proximity scores are derived from the individual perception of risk: 0 – I do not work near other people (beyond 100 ft.)
25 – I work with others but not closely (for example, private office)
50 – Slightly close (for example, shared office)
75 – Moderately close (at arm's length)
100 – Very close (near touching)
The standardised exposure to disease or infections measure is defined by:
0 – Never
25 – Once a year or more but not every month
50 – Once a month or more but not every week
75 – Once a week or more but not every day
100 – Every day

Using ONS data on occupation specific mortality rates from SARS-Cov-2, and correlating this with the occupational proximity scores for the UK, the probability of infection conditional on occupation were then back-calculated for the US population. This modelling then calculated the risk using occupational specific proximity measures for 454 occupations in the USA. These proximity scores appear to be available at more granular level for the US workforce, but specific COVID mortality rates are not available.

Rates of infection per 100,000 within specific occupations were then estimated. In this model, it is clear that HCWs are at risk of the highest *rates* of infection (Ana Babus 2020)(Table 4), but some other occupations come close.

	Emergency Medical technicians and paramedics	Registered nurses	Bus Drivers	Butchers and other meat, poultry, and fish processing workers	Elementary and Middle school teachers	Retail sales persons	Secretaries and administrative assistants	Personal financial advisors
Estimated infection rate (per 100,000)	18,789	15,568	13,590	12,460	11,652	9,432	4,933	3,556

Table 4. Back calculation of the infection rates by Occupation using UK death rates and proximity scores by occupation

Seroprevalence by Occupational group

Data on infection rates can also be estimated from seroprevalence studies but few such studies have collected data by occupation.

The REal-time assessment of community transmission-1 (REACT-1) study is an Imperial/Oxford collaborative which allows for an assessment of community prevalence of SARS-CoV-2 infection over multiple rounds of sample collection since May 2020.

REACT-2 is a seroprevalence study which began sampling in July 2020 across the country. The highest crude prevalence was found to be care home staff in client facing roles (15.1%; 95% CI: 12.7-17.8) followed by healthcare staff in patient facing roles (11.1%; 95% CI: 10.1-12.2%) (Table 5). Antibody prevalence amongst those in other 'essential roles' (see definition of essential workers in the table inset) was 6.1% (95%CI: 5.7-6.4%), similar to that for other work but higher than those not in employment 4.2% (4.0-4.5%).

This confirms the very high cumulative infection rates in HCWs with an odds ratio for infection of 11.7 for patient facing HCW compared to other essential workers (Ward H and Donnelly CA) (Table 4).

	Total antibody positive	*Total tests (with valid results)*	*Crude prevalence % (95% CI)*	*Prevalence % adjusted for test*
Employment				
Health care (patient-facing)	379	3402	11.1 [10.1-12.2]	11.7 [10.5-13.1]
Health care (other)	73	1151	6.3 [5.1-7.9]	6.0 [4.4-7.8]
Care home (client-facing)	115	761	15.1 [12.7-17.8]	16.5 [13.7-19.8]
Care home (other)	12	146	8.2 [4.8-13.8]	8.2 [4.1-15.0]
Other essential worker[1]	1209	19927	6.1 [5.7-6.4]	5.6 [5.2-6.0]
Other worker	2189	37855	5.8 [5.6-6.0]	5.3 [5.0-5.6]
Not in employment	1516	35737	4.2 [4.0-4.5]	3.4 [3.2-3.7]

Table 5. Crude and Adjusted antibody prevalence of Sars-CoV2- in working populations(Ward H and Donnelly CA). In this, essential workers defined by NHS/Social care staff/Essential public services/Public Safety and National Security staff/Transport workers/ Education/Critical workers in food distribution/public and environmental health bodies/Funeral industry workers/Frontline local authority staff/Utility workers.

These figures compare with data from routine serology testing (Pillar 3) primarily in healthcare workers in hospital settings. This testing done largely in late May and June showed an overall seropositivity of 15.4% (10.6-18.5%) amongst the 943,886 individuals tested across England.

VIVALDI-2, a study conducted between June and July 2020, measured the prevalence of antibodies in staff and patients in around 100 care homes across the United Kingdom. Antibody testing was conducted on 3,414 participants; of whom 67% were staff with a sero-positivity of 24.9% (Care 2020). This suggests that care home staff are at even higher risk of infection than health care staff and supports their current JCVI prioritisation.

Mortality rates

Given that the assessment for prioritising vaccine by JCVI in the general population is primarily focused on preventing deaths, data on mortality by occupation is perhaps the most important and relevant data for consideration. Data on age standardised mortality rates (ASR) due to SARS-Cov-2 in the general population are summarised in Table 6. These confirm that age is the key factor with individuals above working age having the highest rates; ranging from 134.3 per/100,000 in those aged 65-69 to 2068.3/100,000 in those who are 85 years and over (Rushton 2020).

Table 6. Age specific mortality per 100,000 due to SARS-CoV-2 (Rushton 2020)

Age-Group	Age-Standardised Mortality Rates
Under 65	16.6
65-69	134.3
70-74	220.3
75-79	452.3
80-84	903.5
85+	2068.3

These data can be compared with ONS statistics of SARS-Cov-2 deaths, by different occupational groups, among men and women of working age (20 to 64 years) in England and Wales during the first wave (provisional analysis, published 26th June 2020).

A total of 4,761 deaths involving COVID-19 amongst the working age population were registered between 9 March and 25 May 2020. Nearly two-thirds of these deaths were among men (3,122 deaths), with the age-standardised mortality rate of death involving COVID-19 being statistically higher in men, at 19.1 deaths per 100,000 men aged 20 to 64 years compared with 9.7 deaths per 100,000 women (1,639 deaths).

The PHE mortality teams have created additional tables based on the ONS data on occupational mortality, divided by occupation and age group (Table 7). This confirms that, even in health care professions and other high-risk occupations, the highest proportion of deaths occur in those aged 50 years and above and therefore a programme targeting this group would have the greatest impact on mortality.

			Age 20-29			Age 30-49			Age 50-64			Total (Age 20-64)		
SEX	Code	Occupation	COVID deaths	Popn.	ASR	COVID deaths	Popn.	ASR	COVID deaths	Popn.	ASR	COVID deaths	Popn.	ASR
Male	1224	Publicans and managers of licensed premises	s	6402	s	s	6579	s	10	4514	221.5	10	17495	57.2
Male	2211	Medical practitioners	s	16001	s	s	69338	s	20	33470	59.8	22	118809	18.5
Male	2231	Nurses/Midwifery	s	7200	s	9	35799	25.1	26	18315	142.0	35	61314	57.1
Male	231	Teaching and Educational Professionals	s	61452	s	7	211991	3.3	38	121334	31.3	45	394777	11.4
Male	3312	Police officers (sergeant and below)	s	15087	s	s	57172	s	13	11660	111.5	14	83919	16.7
Male	5315	Carpenters and joiners	s	36310	s	s	79374	s	36	45079	79.9	40	160763	24.9
Male	5319	Construction and building trades n.e.c.	s	32145	s	12	107594	11.2	46	66302	69.4	59	206041	28.6
Male	5434	Chefs	s	47724	s	16	80948	19.8	**32**	**25432**	**125.8**	50	154104	32.4
Male	6141	Nursing auxiliaries and assistants	s	14608	s	8	20165	39.7	27	15594	173.1	35	50367	69.5
Male	6145	Care workers and home carers	s	27118	s	16	35929	44.5	57	34625	164.6	75	97672	76.8
Male	6221	Hairdressers and barbers	s	3856	s	s	8445	s	9	4089	220.1	10	16390	61.0
Male	7111	Sales and retail assistants	s	111498	s	8	71021	11.3	37	33643	110.0	48	216162	22.2
Male	7124	Market and street traders and assistants	s	2580	s	s	1799	s	10	2292	436.3	11	6671	164.9
Male	8111	Food, drink and tobacco process operatives	s	16253	s	s	29227	s	29	15320	189.3	32	60800	52.6
Male	8213	Bus and coach drivers	s	4961	s	7	27937	25.1	**49**	**42304**	**115.8**	56	75202	74.5
Male	8214	Taxi and cab drivers and chauffeurs	s	13498	s	23	102241	22.5	**114**	**63972**	**178.2**	139	179711	77.3
Male	9120	Elementary construction occupations	s	40141	s	5	47311	10.6	**36**	**25943**	**138.8**	41	113395	36.2
Male	9139	Elementary process plant occupations n.e.c.	s	16879	s	6	23810	25.2	**45**	**13214**	**340.5**	52	53903	96.5
Male	8125	Metal working machine operatives	s	8184	s	s	18119	s	19	13694	138.7	22	39997	55.0
Male	9233	Cleaners and domestics	s	14752	s	7	28797	24.3	33	29068	113.5	40	72617	55.1
Male	9241	Security guards and related occupations	s	27600	s	19	57520	33.0	**90**	**45222**	**199.0**	110	130342	84.4
Female	1224	Publicans and managers of licensed premises	s	4725	s	s	7923	s	5	2862	174.7	5	15510	32.2
Female	2231	Nurses	s	71587	s	15	231371	6.5	57	163319	34.9	74	466277	15.9
Female	6141	Nursing auxiliaries and assistants	s	44749	s	s	93225	s	33	70914	46.5	37	208888	17.7
Female	6145	Care workers and home carers	s	117814	s	23	206631	11.1	126	171702	73.4	150	496147	30.2
Female	7111	Sales and retail assistants	s	152096	s	15	156288	9.6	55	137733	39.9	70	446117	15.7
Female	9139	Elementary process plant occupations n.e.c.	s	2434	s	s	7846	s	10	4396	227.5	11	14676	75.0
Female	9233	Cleaners and domestics	s	48632	s	7	169108	4.1	55	147558	37.3	62	365298	17.0
ASR; Age specific rate														
Data suppressed if COVID deaths less than 5 (denoted by 's')														

Table 7. Selected occupations (encompassing similar to those shown for occupational exposure and proximity) showing deaths and age specific mortality in both males and females. Also shown are the work-force populations.

Men and women working in social care, including care workers and home carers, both had significantly raised rates of death involving COVID-19, with rates of 50.1 deaths per 100,000 men and 19.1 deaths per 100,000 women (150 female deaths with 126 of these deaths occurring in those over 50 years).

Among health care professions as a whole, including those employed as doctors and nurses, only men had higher rates of death involving COVID-19 (30.4 deaths per 100,000 men or 130 deaths) when compared with the rate among those whose death involved COVID-19 of the same age and sex in the general population; of the specific health care professions, nurses had elevated rates among both sexes (50.4 deaths per 100,000 men or 35 deaths; 15.3 deaths per 100,000 women or 74 deaths).

Due to the higher number of deaths among men, ONS data indicated 17 specific occupations that were found to have raised rates of death involving COVID-19, some of which included: taxi drivers and chauffeurs (65.3 deaths per 100,000; 139 deaths and 114 of whom were in over 50 years); bus and coach drivers (44.2 deaths per 100,000; 56 deaths and 49 in those > 50 years); chefs (56.8 deaths per 100,000; 50 deaths); and sales and retail assistants (34.2 deaths per 100,000; 48 deaths and 37 occurred in those greater than 50). Of the remaining major occupational groups with high rates among men, those who worked in process, plant and machine operative occupations had one of the highest number of deaths overall (473 deaths).

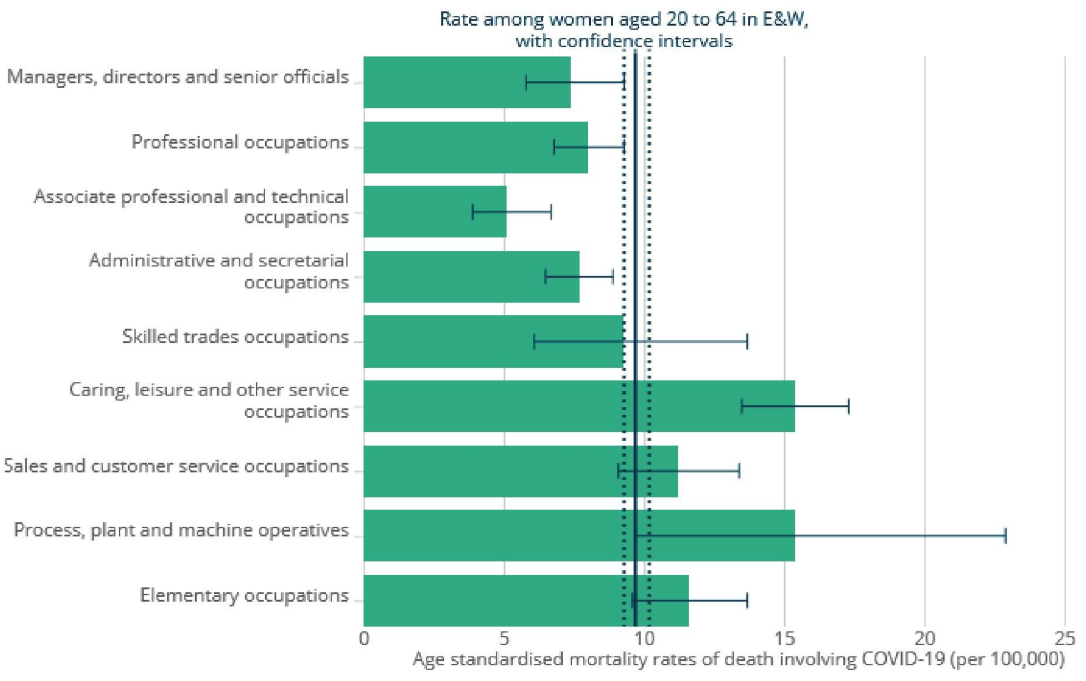
Compared with the rate among people of the same sex and age in England and Wales, men working in elementary occupations had the highest rate of death involving COVID-19 (Figure 3B), with 39.7 deaths per 100,000 men (421 deaths). Of the specific elementary occupations, men working as security guards had the highest rate, with 74.0 deaths per 100,000 (110 deaths). Within this the rate in under 50s was significantly lower than in the 50-64 age groups (33 in 30-49 versus 199 in the 50-64 age group). (see table 7).

Women working in caring, leisure and other service occupations had the highest rate of death involving COVID-19 compared with women of the same age in the general population (Figure 3A).

Of the 17 specific occupations among men in England and Wales found to have higher rates of death due to Sars-CoV-2, data from the Annual Population Survey (APS) show that 11 of these have statistically significantly higher proportions of workers from Black and Asian ethnic backgrounds; for women, APS data show that two of the four specific occupations with elevated rates have statistically significantly higher proportions of workers from Black and Asian ethnic backgrounds.

To put into overall context, by ASR in males in the selected non-HCW roles (Table 7), the range was 3.3-33 for ages 30-49, 31.1-340.5 for ages 50-64 and similarly for females, the range in 30-49 was 4.1-9.6 and 37.3-227.5 in the 50-64 age group. Similarly, in healthcare roles, an age discrepancy also exists (males: ASR 25.1-44.5 in 30-49 years and 59.8-173.1 in 50-64 age group; males: ASR 33-126 in 30-49 years and 37-150 in the 50-64 years).

Overall whilst there is evidence of an increased risk of infection amongst HCWs, the highest mortality rates are not observed in this group. This probably reflect the different demographic make-up of these groups, including age, gender, underlying co-morbidities and factors such as ethnicity and deprivation.



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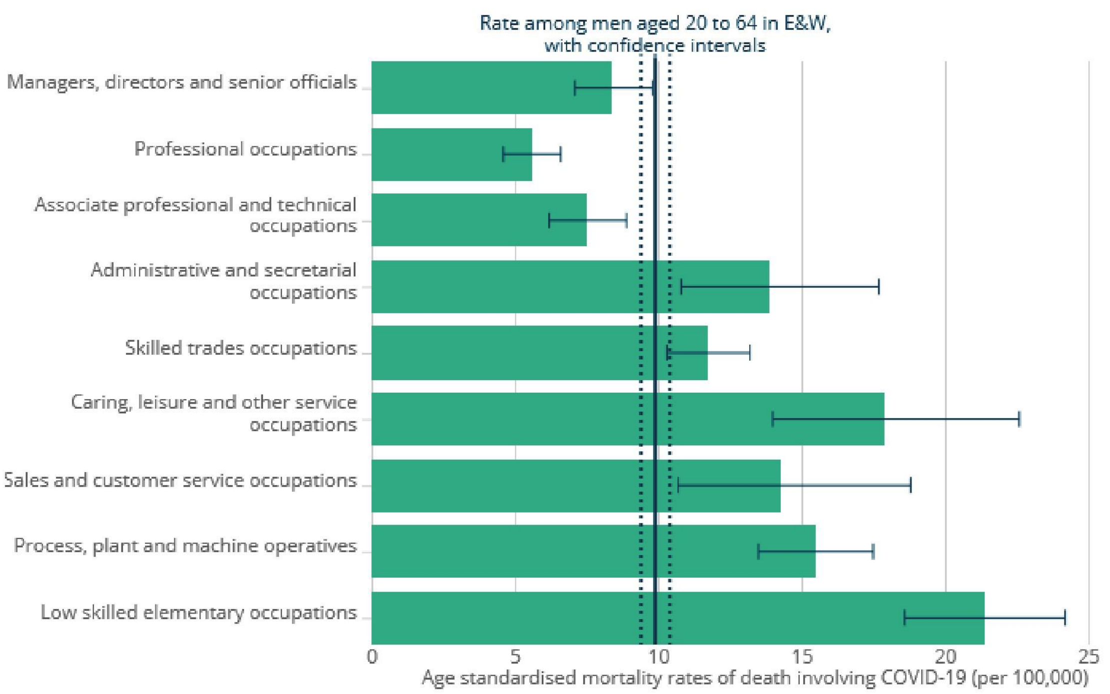

B

Figure 3. Mortality rates involving SARS-COV-2 in women by occupational group (A) and in men (B). Figure taken from (Butt 2020). Note that the 4 key highest risk groups are elementary occupations, health-care workers, sales staff and machine operators.

Modelling vaccination allocation by Occupation

The UK model from Warwick that was used as part of JCVI's deliberations had also looked at a vaccination programme for healthcare professionals. A focused vaccination programme (where efficacy is ~ 50% and coverage 70%) suggests that vaccinating health care workers would be favoured to reduce HCW deaths (Figure 4)(Sam Moore 2020). This assumes a hazard ratio for infection of 3.40 in healthcare professionals and a reproductive number of 1.8 (Sam Moore 2020).

In this model, this HR of 3.4 equates to adding around 10 years of age specific risk to the affected individual (personal correspondence), and places vaccination of all health care staff over the over 60s. Provision of a vaccination is also assumed to prevent onward transmission from health care staff to vulnerable individuals. These findings support the current prioritisation with healthcare workers being prioritised alongside older adults aged 80 years and above.

A US model, based on an assumption of vaccine efficacy of 70% in 18-64 years old, suggest that vaccine in healthcare personnel decrease rates of infection by 3.5% and death by 3.3%. Vaccination of other essential workers (which are not defined) have their infection rate reduced by 3.1%(Rachel B. Slayton 2020). The same group looked at the impact of vaccinating care-home workers and demonstrated a striking reduction in deaths and infections through this focused vaccination strategy of staff (Figure 5).

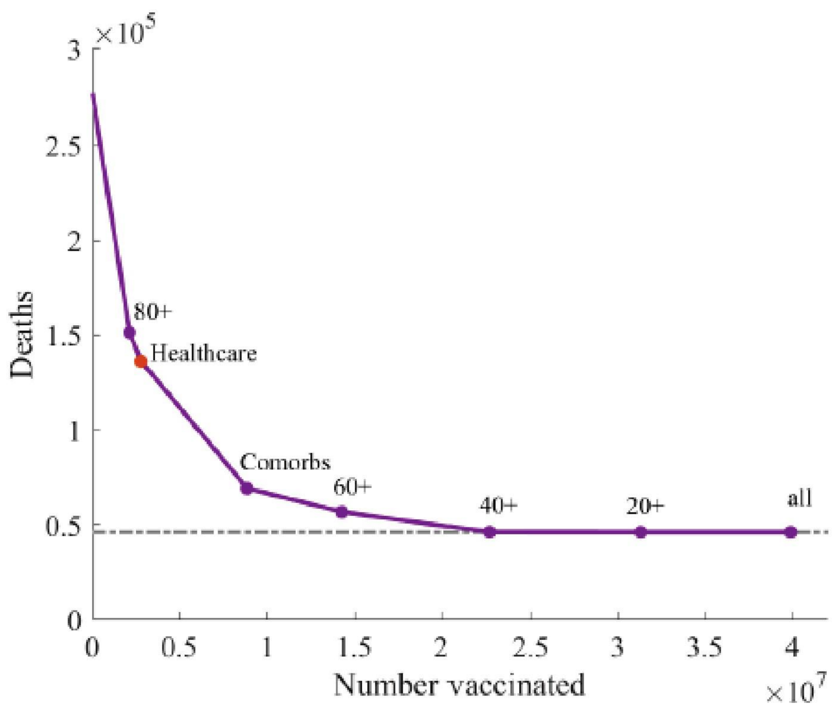

Figure 4. Optimal vaccination ordering for age, comorbidity and HCW groups where vaccine efficacy is 50% and delivered to 70% of the population. (Sam Moore 2020).

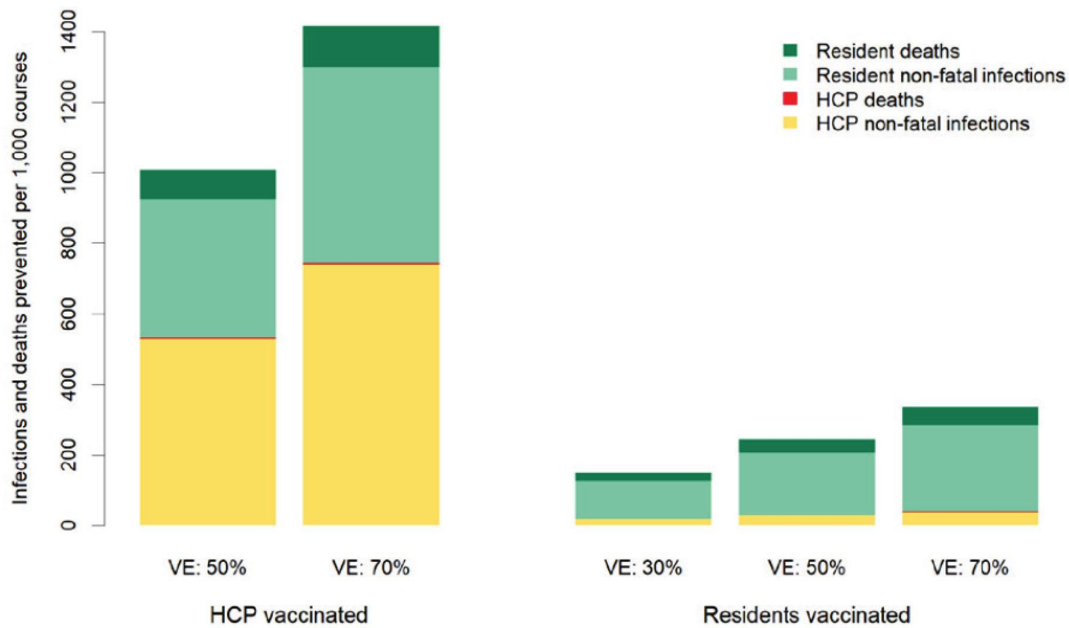

Figure 5. Focused vaccination of healthcare workers in nursing homes in US model leads to a reduction in deaths and infections (Rachel B. Slayton 2020).

The US model by the Babus Group that estimated the infection rates for 454 occupations appears to be the only model that looks at vaccine allocation for a wide range of other specific professions. (Ana Babus 2020). Based on the modelled infection rates using proximity information, the age specific mortality by occupation was estimated for the US.

The mortality risk over a 2-month time frame was estimated using an age-specific infection fatality rate (IFR) (derived in France). As the risk of infection was derived from UK mortality data and the IFR used was similar to the UK values derived from the REACT study (Table 8), this is likely to be generalisable to the UK situation.

By estimating the infection risk by occupation, they then determined the optimal vaccine distribution to minimise mortality, under a constrained supply. Similar estimates of the overall burden of this SARS-Cov-2-specific mortality averted were also conducted, using the value of a specific life (which approximates more closely to life years lost as it allows for overall life expectancy). This model did not include any dynamic elements, so impact on transmission was not included.

Table 8: Infection Fatality Ratio and estimated total numbers of deaths
https://www.medrxiv.org/content/10.1101/2020.08.12.20173690v2.supplementary-material

Category	*Population size*	*SARS-CoV-2 antibody prevalence% (95% CI)[1]*	*Confirmed COVID-19 deaths**	*Infection fatality ratio % (95% CI)[2]*	*Estimated number of infections (95% CI)*
Total	56,286,961	6.0 (5.7, 6.8)	30180	0.9 (0.9, 0.9)	3,362,037 (3,216,816; 3,507,258)
Sex					
Male	27,827,831	6.2 (5.8, 6.6)	18575	1.1 (1.0, 1.2)	1,729,675 (1,614,585; 1,844,766)
Female	28,459,130	5.8 (5.4, 6.1)	11600	0.7 (0.7, 0.8)	1,633,785 (1,539,821; 1,727,749)
Age					
15-44	21,335,397	7.2 (6.7, 7.7)	524	0.0 (0.0, 0.0)	1,535,884 (1,436,941; 1,634,826)
45-64	14,405,759	6.2 (5.8, 6.6)	4657	0.5 (0.5, 0.5)	895,238 (837,231; 953,244)
65-74	5,576,066	3.2 (2.7, 3.7)	5663	3.1 (2.6, 3.6)	181,044 (153,426; 208,661)
75+	4,777,650	3.3 (2.5, 4.1)	19330	11.6 (9.2, 14.1)	166,077 (131,059; 200,646)

[1]All estimates of prevalence adjusted for imperfect test sensitivity and specificity (see text for details). Responses have been re-weighted to account for differential sampling (geographic) and for variation in response rate (age, gender, ethnicity and deprivation) in final column to be representative of the England population (18+); [2] Infection fatality ratios were calculated excluding care home residents. Confirmed COVID-19 death counts were obtained from https://fingertips.phe.org.uk/static-reports/mortality-surveillance/excess-mortality-in-england-week-ending-17-Jul-2020.html. Deaths in care homes by age on 12 June 2020 were obtained from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/deathsinvolvingcovid19inthecaresectorenglandandwales/deathsoccurringupto12june2020andregisteredupto20june2020provisional. Total deaths in care home residents up to 17 July 2020 were obtained from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/numberofdeathsincarehomesnotifiedtothecarequalitycommissionengland. The age stratified estimates of COVID-19 deaths were then estimated using the total deaths from 17 July and the age distribution from 12 June. We assume the age distribution of deaths did not change between 12 June and 17 July 2020.

This model was then used this to determine the optimal vaccine allocation strategy by occupation. Under the scenario a vaccine of 50% efficacy, with a constrained supply, they concludes that it is more beneficial to vaccinate some older HCWs compared to other occupations. (Ana Babus 2020). Vaccination of a limited number of older people in other occupations came close to the achieving the same benefit as some health care professionals. This included some of those in transport and food production, however, it should be noted that the base model assumed that all these professions continued to work.(Appendix 1; Figure 1)

An example of how this type of allocation should work with some key occupations is shown in table 8). As more vaccine becomes available other occupations become eligible at a younger age, but the relative priority remains the same. Overall, they concluded that allocation by age should dominate a policy of vaccine allocation to designated priority professionals. Indeed, designating priority occupations (who would be vaccinated regardless of age), actually led to a slight increase in overall mortality rate (table 9 and appendix 1 figure 1). This was because vaccine supply would be diverted to younger people at lower risk, thus reducing supply to older people in other occupations. Based on existing JCVI advice to extend vaccination to age 50, people in all occupations would be offered vaccine as part of the existing age-based prioritisation strategy.

70+								
60-69								
50-59								
40-49								
30-39								
20-29								
	Emergency Medical Technicians And Paramedics	Registered Nurses	Bus Drivers	Butchers And Other Meat, Poultry, And Fish Processing Workers	Elementary And Middle School Teachers	Retail Salespersons	Secretaries And Administrative Assistants	Personal Financial Advisors
Estimated Infection per 100k	18,789	15,568	13,590	12,460	11,652	9,432	4,933	3,556

Table 8: Priorities among some selected occupational groups. The groups with the top priority are shaded in the darkest blue, and they receive vaccine even when the supply is 30 million doses. Lighter blue marks the groups that have the second and third priority, and they will get vaccines when the supply is 60 million and 100 million doses respectively, the other groups with the lowest priority are shaded white.

Further options that were modelled included a scenario where stay-at-home orders were used and assumed perfect compliance. In these models, some occupational groups were designated "essential" workers who would not stay at home; all older workers (over 70) and all non-essential occupations were mandated to stay at home. Within the essential occupations who continued to work, those above a certain age would receive vaccine and those under that age would work as normal. This achieved a greater overall mortality reduction, but again the over mortality was higher when some occupations were prioritised (i.e. vaccinated regardless of age).

Vaccination policy	Mortality rates per 100,000 people
Simple vaccination policy	11.3
Vaccination with prioritized occupations	11.46
Vaccination and stay-at-home order with essential occupations	8.03
Vaccination & stay-at-home order with essential & prioritized occupations	8.26

Table 9. Consequences of vaccination policies(Ana Babus 2020).

This model, which does not include any consideration of transmission from the workers, also adds further support to an age-based prioritisation policy rather than vaccination of key occupations regardless of age.

Conclusion

In this report, we show that healthcare workers have been at high risk of infection, disease and death during the pandemic. This is likely to stem from the close and frequent proximity to other people, combined with the high risk of infection in those people. This is reflected in increased incidence rates, high sero-prevalence and increased death rates. Data on infection rates in occupations other than health care and care home staff is limited, but overall seems to be lower. Infection rates have been back-calculated for 454 occupations in US, based on UK data, and does confirm that only a small number of other occupations have rates of infection approaching those of health care staff. UK case data has also demonstrated a high risk for some occupations other than care, such as meat processing workers, and clusters of infection in these groups have been noted during the pandemic.

Mortality data in the UK has indicated that some other occupations are at higher risk of death from COVID, particularly for men. Mortality risk in these other occupations most likely reflects a combination of moderate infection rates with a high proportion having underlying clinical and demographic risk factors for severe disease. UK modelling of the expected mortality in health care workers, assuming around a 3-fold increased risk, would support them being prioritised along-side those over 80 years of age, with the additional advantage that this may reduce secondary transmission to highly vulnerable patients.

We were unable to find many models which looked at other occupations. A model built for the US, which looked mainly at the direct prevention of mortality and did not take account of onward transmission, clearly demonstrated that age should dominate consideration of occupation in vaccine allocation. It recommended vaccinating the older members of most occupations, and that there was a case for vaccinating some occupations, including health care professions, down to a lower age cut-off. It did not recommend designating some occupations as priorities for vaccination, that is that all members of that occupation would be eligible, because this would divert scarce vaccine supply from older people in other occupations who were at higher risk. Although this model has not been constructed for the UK, examination of mortality rates by age and gender for those occupations at high risk, shows that the absolute risk in under 50s remains very low compared to the background population rates in older individuals. This would support the dominance of the age-based policy. Given that the JCVI has advised that everyone over 50 years of age should become eligible for vaccination, plus those with recognised clinical risk factors below this age, this analysis would suggest that additional prioritisation by occupation should be limited and deferred, as vaccine would be diverted from older people at higher risk.

JCVI may wish to restrict any occupational considerations, on top of the current age-based criteria, based on the following criteria

- Those occupations at very high risk of infection
- Those where may a risk of onward transmission to vulnerable individuals (if the vaccine is expected to reduce transmission)
- To older members, or those with recognised co-morbidity, of occupations at lower risk of infection

As JCVI has already defined an initial prioritisation to healthcare workers, based on the mortality data, they may wish to also consider whether this recommendation should be regardless of age for all staff groups or whether to limit the initial recommendation by age, gender or the nature of the care work. Following this and as a final statement, as we have shown in table using our own mortality data, the largest rates of death incurred by HCW are those in older age-groups, therefore do we consider with vaccine allocation, to reduce death in the individual through age-prioritisation of HCW or to vaccinate all age groups with the likelihood that this will have an effect on onward transmission?

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Appendix 1

Figure 1

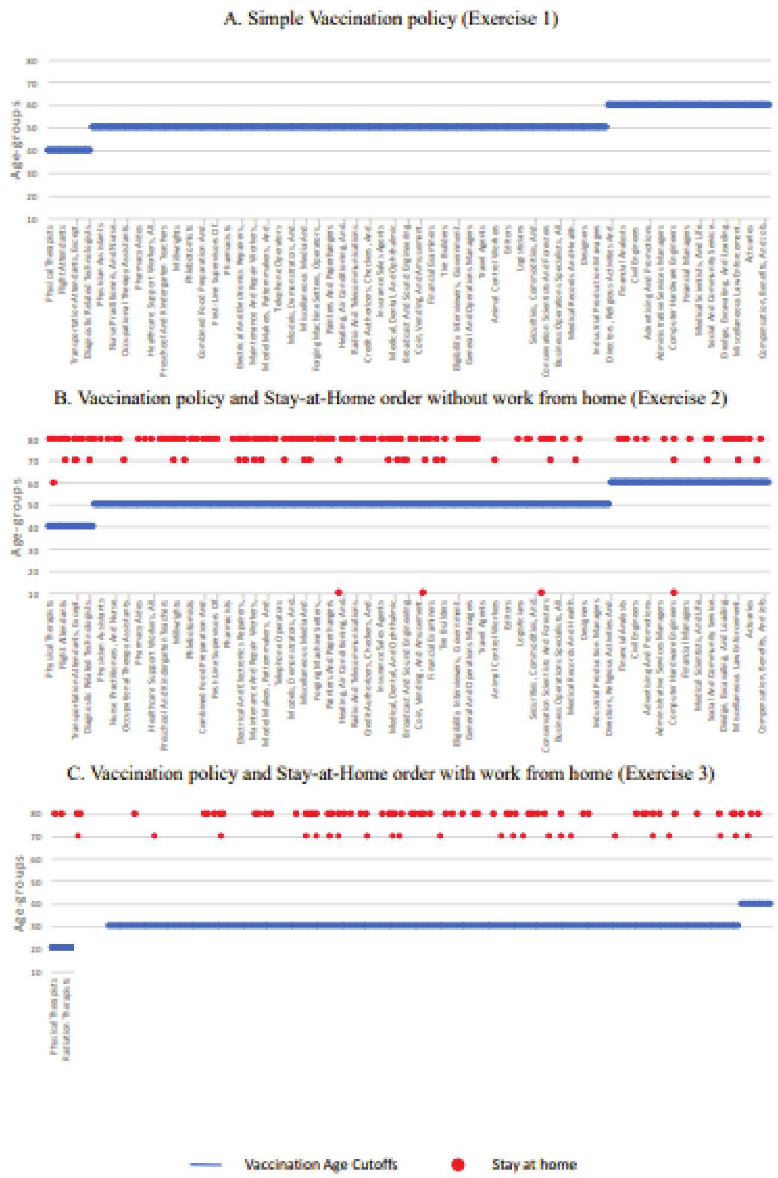

Figure 1: Age cutoffs for vaccinations and age groups staying at home. Occupations on the x-axis are ordered based on their infection risk. (A) The optimal vaccination policy showing the youngest age for each occupation that is eligible to receive the vaccine. (B) The optimal vaccination policy showing the youngest age for each occupation that is eligible to receive the vaccine, together with the occupation-age groups that are mandated to stay at home. (C) The optimal vaccination policy showing the youngest age for each occupation which cannot be done from home that is eligible to receive the vaccine, together with the occupation-age groups that are mandated to stay at home. Occupations that can be done from home do not receive a vaccine.