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Risk Stratification for Healthcare workers during the CoViD-19 Pandemic; using *demographics, co-morbid disease and clinical domain in order to assign clinical duties*

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Abstract

Background: Healthcare workers have a greater exposure to individuals with confirmed SARS-novel coronavirus 2, and thus a higher probability of contracting corona virus disease (CoViD)-19, than the general population. It is critically important, therefore, for health systems to protect the lives of their staff especially those on the frontline. Urgent work is needed to identify how best to protect those most at risk in an evidence-based way in order to implement protective allocations. We wished to explore the predictive role of basic demographics in order to establish a simple tool that could help risk stratify healthcare workers.

Objectives and Study question: To develop a risk stratification tool for use to assist staff allocation by examining reported demographics of hospitalisation and mortality in the UK from CoViD-19 compared to population demographics and historic admissions for viral pneumoniae.

Setting: Secondary Care in the UK and worldwide.

Participants: Patients and Health Care Professionals hospitalised and dying of CoViD-19.

Methods: We undertook a review of the published literature (including multiple search strategies in MEDLINE with PubMed interface) and critically assessed early reports on medRxiv, a pre-print server (https://www.medrxiv.org/) (date of last search: April 30, 2020). We explored the relative risk of mortality from readily available demographics in order to identify the population at highest risk.

Results: The only published studies specifically assessing the risk of healthcare workers had limited demographics available, therefore we explored the general population in the literature.

Clinician Demographics. Mortality increased with increasing age from 50 years onwards. Male sex at birth, people of black and minority ethnicity groups had higher susceptibility to both hospitalisation and mortality.

Co-morbid Disease. Vascular disease, diabetes and chronic pulmonary disease further increased risk. Those with pre-existing mental health issues may also be more likely to experience emotional trauma, depression and anxiety with consequences for self-harm too.

Risk stratification tool. A risk stratification tool was compiled using a Caucasian female <50years with no comorbidities as a reference. A point allocated to risk factors associated with an approximate doubling in risk. This tool provides numerical support for healthcare workers when determining which team members should be allocated to patient facing clinical duties compared to remote supportive roles.

Clinical Domain. Those working with aerosol generating procedures were at increased risk, however healthcare workers in any clinical domain are at higher risk than the general population.

Conclusions. We have generated a tool which can provide a framework for objective risk stratification of doctors and health care professionals during the CoViD-19 pandemic.

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What this study adds:

- There is potentially an increased risk of mortality in the clinical workforce due to the effects of CoViD-19.
- This manuscript outlines a risk stratification tool that may help quantify an individual's personal risk
- This may be used when allocating roles within clinical departments.
- This tool does not incorporate other external factors, such as high-risk household members, that may require additional consideration when allocating clinical duties in an appropriate clinical domain.

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Introduction and Background.

Coronaviruses are a common cause of upper respiratory tract infections, both in adults and children, causing ~20% of such infections (1,2). Infections usually last for several days and have a mild course. For those less than 40 years, up to 40% are completely asymptomatic.

Since the pandemic of CoViD-19 disease caused by the novel SARS-CoV-2 virus first started in December 2019, there have been vast differences in its morbidity and mortality, ranging from <1% to 15% in different geographical locations (1-4). The variations have been attributed to multiple determinants of pathogenesis; host fitness including immunocompetency, the viral inoculum dose, potential variations to the viral genome, patient comorbidity, and the capacity of local healthcare services to provide care (5).

Health Care Professionals (HCPs) have a greater exposure to infected patients with advanced disease. As a result, the risk of infection has been reported to be higher in healthcare workers compared to the general population. Worldwide, there have been ~235,000 known CoViD-19 related deaths, of which ~ 1000 are health care professionals. As of 22nd April, there had been 21,000 deaths in the UK of whom 119 (~0.5%) were health care workers, approximately a 2-5 fold increased risk compared with an age matched population (6). The exact reason for this is not fully understood, however it is believed to be in part due to their contact with patients who have advanced disease, or by involvement in aerosol generating procedures (AGP) such as endoscopy, intubation tracheostomy, suction and resuscitation(7-11). As the occupational health risk is not fully understood it is not possible to completely neutralise the risk of increased exposure. Therefore, there is a need for a tool to identify those individuals at highest risk of an adverse outcome from CoViD-19 in order to allocate roles with minimal exposure to those with viral load, through either working at "cold" sites with people who have have been confirmed to be negative for infection, or by working remotely providing advice and guidance to patients or other specialties.

Here we review the demographics of those who have been hospitalised, and ultimately died, due to CoViD-19 compared to the general population in order to develop a risk stratification tool.

Methods.

We reviewed the published literature (including multiple search strategies in MEDLINE with PubMed interface) and critically assessed early reports on medRxiv, a pre-print server (https://www.medrxiv.org/) (date of last search: April 30, 2020). Given there are selection biases in testing for coronavirus, CoViD-19 care and reporting, we explored predominantly the 'hard outcomes' of mortality and admission to the intensive care unit. Further, the majority of the existing analyses, are based on retrospective and often single-centre series. No published or completed prospective cohort studies or randomized controlled trials were present in this literature search. We reviewed the case reports and cohort studies and where possible the local demographics. Risk for age (12), ethnicity (13), socioeconomic status (13), and co-morbidities (14) was normalised to a male aged 50-59.

Once collated and compared to the risk within the general population a simplified risk calculator was produced. The risk of mortality of a female under the age of 50 years of age

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was used as the reference. This assigned a point to an approximate doubling in risk. Given the likely co-linearity of multiple risk factors where risk was a greater multiple than two it was rounded down.

Results.

There were no studies specifically describing the risk factors of health care workers, beyond gender and ethnicity. Multiple global observational studies were identified describing the risk of hospitalisation and mortality due to CoViD-19, however there was significant heterogeneity in these studies, such that the robust nature of the data when applying to a Western population of health care providers was questionable (Supplementary table 1). One point of agreement, however, was that multiple co-morbidities appeared to confer cumulative risk. As a result, the development of a risk calculator was based exclusively on UK data, with multiple co-morbidities being given additive weighting.

Clinician Demographics.

Age and sex. In all age groups, mortality was at least twice as high in men as in women (Table 1). Compared to those under the age of 50, mortality was doubled in 50-59 years olds, quadrupled in the 60-69 age group, and 12 times higher after the age of 70 in men. In addition, the time from infection to death was shorter for patients older than 70 years as compared to younger patients (the median times were 11.5 and 20 days, respectively).

Ethnicity.

People of non-white ethnic origin appear to be at a higher risk of hospitalisation and mortality than the general population. This is most accentuated in people of black African descent where the risk was two-fold elevated compared to those of White European descent. People of Indian Asian descent also had an approximately a 50% increased risk of hospitalisation compared to their European counterparts. This is both when compared to the local population, and occurrence of COVID-19 compared to non-COVID-19 viral pneumoniae over the previous 3 years (Table 2). In the UK health service, however, this is further exaggerated. Up to the 21st April, 38% of health care workers who had died as a result of COVID were of white European descent despite representing 79% of the total workforce. Whereas 36% and 27% of the fatalities came from people of Indian Asian and Black African descent respectively, despite those populations only representing 10% and 6% of the work force, suggesting in excess of 3-fold risk for those of Indian origin and a 4-fold risk for those of Black African origin.

Socioeconomic status. As with flu, 25% of ICU admissions are people from most deprived quintile as evaluated compared with just 15% in least deprived (Table 2). Once on ITU, however, there were only slight differences between people in the most deprived vs least deprived status.

Co-morbidities.

There were multiple co-morbid factors that were each incrementally associated with increased mortality. The most common recorded comorbidities are chronic cardiac disease (29%), uncomplicated diabetes (19%), chronic pulmonary disease excluding asthma (19%) and asthma (14%) (table 3)(15). When comparing to background prevalence of disease,

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these represented 16,749 patients: 7,924 (47%) patients had no documented reported comorbidity. Although numerically not a large percentage of patients, those with active malignant neoplasms and rheumatological diseases were at a 6 and 11-fold increased risk of hospitalisation respectively compared to the prevalence in the general population. Similarly, dementia was associated with a significantly higher risk than the general population of both hospitalisation (~7.7 times increased) and mortality in hospital (39% increase). This has limited relevance for modifying clinical exposure, although may be of pertinent if using this tool to assess risk within the community. Contrary to many popular media reports, there was only a marginal rise in the hospitalisation and mortality in people living with obesity, such that the composite increased risk was less than a 2-fold increased risk. Given the collinearity between obesity and ischaemic heart disease, chronic pulmonary disease and type 2 diabetes, it was decided not to include obesity as an independent predictor of adverse outcome.

Generating a risk stratification score

By considering each of the demonstrated associated factors for CoViD-19 hospitalisation and subsequent mortality, we generated a risk stratification tool that may be considered when allocating clinical individuals to standard or higher risk duties (table 4). This used a female healthcare worker under the age of 50 years with no comorbidities as the reference. This translates to an absolute risk of 1% risk hospitalisation and 0.2% mortality from CoViD-19 infection. The risk model then attributed a point for every approximate doubling of risk compared to this reference population. By adding the risk score from each category, it gives every individual a personal risk score which provides an estimate of their relative risk.

Mental health. There is no data to indicate whether healthcare workers with pre-existing mental health conditions are more at risk. However, given that >50% of healthcare workers with pre-existing mental health conditions experience depression and anxiety and >70% of them feel traumatised during CoViD-19 duties, it seems plausible this group will need special consideration (15). Data from Korea, and Italy indicate that suicide risks are >25% greater in healthcare workers who had been managing people with COVID-19. There is likely to be an increase in post-traumatic stress disorder in doctors on the front line (PTSD). Quantification of this risk, however, was not possible from the information available.

Clinical Domain and Medical Roles during CoViD-19 Pandemic.

Once risk is calculated, the nature of exposure needs to be considered. The impact of recurrent exposure compared to high-risk exposures with high viral load, or the environment of the clinical domain is uncertain. Likewise, the relative impact of different environments has not adequately been assessed. Regardless, employees in front line emergency and acute medical settings such as A&E medicine, anaesthesia, respiratory medicine, gastroenterology may be considered at increased risk, as may be those who may need very close proximity with the patient such as ENT and ophthalmology.

There is a lack of robust data on the impact of repeated low-level exposure to virus, however, there is a suggestion that it could result in accumulation of viral inoculation over a short time frame such as occurs in General Practice and Outpatient settings (16). Indeed, one recent paper found that the rate of infection with CoViD-19 in staff in patient-facing occupations was no different from that in clerical/administrative staff without patient

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contact(16). This may suggest that demographic factors and underlying health status have greatest influence on risk. Alternatively, it may be that those with severe illness (particularly at the time of cytokine storm requiring high dependency care) have reduced viral load and shedding therefore paradoxically are a lower infection risk compared to those at an early stage of the disease with no or relatively mild symptoms.

Discussion.

There are currently no reliable data for CoViD-19 related deaths in health care professionals including doctors; and surprisingly few data on the differences in risk in different healthcare settings. There is an urgent need for high quality research. We have applied general population risk factors to health care workers in order to generate a risk stratification tool that may assist teams when allocating specific duties within the health care provision system.

It is important to acknowledge that any patient contact in the current climate comes with some risk given the unknown true prevalence of the coronavirus, and of its infectiousness at different stages in disease. Those with the highest risk score could be allocated roles in which there is little or no direct contact with patients; roles such as “advice and guidance” services, or virtual clinic provision. Those with the lowest risk may be better able to perform the higher risk roles. This risk stratification, however, does not in any way replace the need for universal precautions with appropriate personal protective equipment.

There are three types of risk for medical staff. The first relates to their demographics (age, sex and ethnicity); the second relates to co-morbidities that have accrued through life; and the third relates their knowledge of, access to, and use of PPE. Physiological factors increase immunosenesence; but there is also the potential of workplace related influences too, especially around environmental risk; access to appropriate PPE, training effectiveness, and the confidence to raise concerns.

The observation that increasing age is associated with a poorer outcome in this viral illness is not surprising, although the inflection point of increased risk at the age of 50 is somewhat lower than we may anticipate. The doubling in risk for those born as males compared to females, however, is novel to this particular virus. Although this may be a result of increased prevalence of “at risk” comorbidities, there is work to suggest that ACE2 enzyme levels are twice as high in men compared to women. Given that the ACE2 enzyme is the cellular entrance route for this virus, that may contribute to this biological phenomenon.

The importance of pre-existing cardiovascular disease and cerebrovascular disease is a novel observation for a respiratory disease. Whereas inflammatory and atherogenic complications of viral illnesses such as influenza have been described, they have not previously featured as risk factors for contracting viral infections such as the H1N1. This may be due to the method of cellular invasion of the virus using the ACE2 enzyme; an enzyme which is responsible for physiological vascular health responses to hypertension and obesity. It does not explain the risk associated with diabetes, however, given that diabetes and the associated chronic hyperglycaemia and dyslipidaemia reduces the ACE2 enzyme expression.

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Some ethnic groups of the clinical workforce are potentially at risk more than others. In particular a recent finding showed that Black, Asian and minority ethnic (BAME) individuals account for 63 per cent, 64 per cent and 95 per cent of deaths in the Nurse, Health Care Assistant and Doctor staff groups, respectively. BAME patients also account for a higher proportion of patients admitted to UK intensive care units (deaths 18%) with CoViD-19 when compared with a 14 per cent of the UK population.

It is not clear how these risk factors relate to the endogenous genetic or cultural factors or exogenous workplace related issues such as confidence of BAME staff raising safety concerns. Co-morbidities could certainly play a role. The rate of both hypertension and diabetes is higher in the Black population, where the discrepancy appears to be greatest. Both conditions increase the risk of death once CoViD-19 is confirmed. These conditions occur on average 10-years younger in people of black descent.

By contrast, smoking rates are lower in older people of black African descent leading to less respiratory disease, and lower rates of cancers and coronary disease. Within Asian populations the story is a bit different, but again there is a four-fold excess in diabetes, and blood pressure rises higher with age in people of Indian subcontinent heritage compared to Europeans (17).

The discrepancy between the risk seen in BAME individuals in the general population and that in healthcare workers is an important consideration that cannot be explained by the published data. Despite the significant disparities in risk, however, this is unlikely to be due to fundamental biological differences between BAME healthcare workers and the general population. We propose, therefore, that the increased risk may be due to previous risk stratification methods not considering ethnicity as an independent factor. Some hospitals are collegiate while others are coercive. As a consequence, certain groups of doctors are more vulnerable in uncertain and ambivalent circumstances. Indeed, this culture has been proposed as a contributor to the increased risk in BAME populations.

The primary role of this tool is to identify those at highest risk of experiencing severe illness or dying. From existing data, it is impossible to identify the risk of contracting the infection, however, we would argue that the risk of incident infection with no or mild symptoms does not require additional modification of the workplace beyond that which is recommended for all healthcare workers. The workplace specific factors, such as the speciality of the doctor, the level of training and support, ensure they stay compliant with safe practice. In this regard the availability of appropriate PPE is paramount but so is the training to use it. Moreover, the buddy system to ensure safe donning and especially doffing may provide additional security (Table 5).

The purpose of the risk stratification tool is to inform the hazards that our in our control, namely the clinical domain in which the doctor works. It will enable employers to decide when to exclude workers from working in higher risk environments such as front line work - even if they wish to do so - in order to fulfil the employers' legal duty of care obligations to their work force. It may also inform some people when to self-confine because they pose too great a risk to others either by directly infecting others or indirectly by creating an

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unacceptably high probability of high demand on NHS services compared with the 'unlocked' population.

It must also be acknowledged that this tool is based purely on biological risk of an individual. The prevalence of the disease in the community is another determinant which should be considered; when prevalence is low, the increased relative risk may not reflect a significant rise in absolutely risk allowing health care practitioners to return to their usual role.

Study limitations.

Selection bias in testing, care and reporting can lead to differences in prevalence estimates of pre-existing risk factors and presentation across the reports from various countries. The majority of the existing analyses are based on retrospective and often single-centre series. No published or completed prospective cohort studies or randomised controlled trials were present in this literature search. There is an urgent need for high quality research, using patient level data that will allow full mediation analyses in order to determine whether (for example) it is the age, the diabetes, or the cardiovascular disease that actually carries the greatest prognostic risk, given that these conditions commonly co-exist. There are currently only limited observational data for CoViD-19 related deaths in health care workers or doctors, again without full access to all potentially pertinent information.

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Concluding Remarks and Key Messages.

There is an urgent and immediate need that every single doctor has a formal risk assessment. There also needs to be appropriate, detailed consent for all doctors who are being asked to work in patient facing areas, so they also understand their risks. All doctors should wear appropriate PPE for any clinical examination or investigation on the basis that 20-40% of patients, especially if less than 40 years of age maybe asymptomatic.

Within a team, an assessment of risk score may help guide allocation of duties, with the patient facing roles being taken by the appropriately trained member at lowest risk. Clearly this should also consider in other factors such as the local prevalence of the SARS-CoV-2, many of whom will be asymptomatic. Within a specialty team, the highest risk individuals should be excluded from patient facing clinical areas; those at intermediate risk should have careful consideration to exclude them from front line areas or give limited duties avoiding close contact such as ENT, ophthalmology and dentistry. Those at the lowest risk may be assigned duties with more patient contact, however the risk score does not negate the need for good personal protective equipment and training.

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Table 1. Clinician Demographics. Mortality by age group and risk of admission and subsequent mortality stratified by sex at birth (Features of 16,749 hospitalised UK patients with CoViD-19 using the ISARIC WHO Clinical Characterisation Protocol) (18).

Age group	**Mortality**
<50years	1 (reference)
50-69	4.02 (2.88-5.63)
70-79	9.59 (CI 6.89, 13.3)
≥80years	13.59 (CI 9.79, 18.85)
Sex at Birth	
Proportion of admissions	
Male	60.2%
Female	39.8%
Mortality once admitted	
Male	1 (reference)
Female	0.80 (CI 0.72, 0.89)
Composite risk	
Male	1 (reference)
Female	0.528

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Table 2. Comparison of hospitalisations with CoViD-19 in the UK compared to admissions in similar geographic locations with non-CoViD-19 viral pneumonia in previous 3 years.

Demographics	Patients with COVID-19 (n=6720)	Patients with (non-COVID-19) viral pneumonia from 2017-19 (n=5782)
Sex, n (%)		
Male	4822 (71.8)	3141 (54.3)
Female	1894 (28.2)	2641 (45.7)
Ethnicity, n (%)		
White	3938 (65.7)	4951 (88.4)
Mixed	94 (1.6)	52 (0.9)
Asian	925 (15.4)	325 (5.8)
Black	639 (10.7)	155 (2.8)
Other	397 (6.6)	117 (2.1)
Index of Multiple Derivation quintile, n(%)		
1 (least deprived)	945 (14.8)	873 (15.3)
2	1030 (16.0)	999 (17.5)
3	1263 (19.6)	1115 (19.5)
4	1598 (24.8)	1232 (21.6)
5 (most deprived)	1591 (24.7)	1489 (26.1)
Body Mass Index (kg/m^2), n (%)		
<18.5	39 (0.6)	310 (5.5)
18.5 - 24.9	1579 (26.3)	1933 (34.2)
25 - 29.9	2077 (34.6)	1691 (29.9)
30 – 39.9	1871 (31.2)	1330 (23.5)
>40	439 (7.3)	394 (7.0)

Table 3 - Composite risk of contracting CoViD-19 and mortality by pre-existing co-morbidity

	Prevalence in CoViD-19 (18)	Prevalence in population	Relative risk of contracting disease	Additional Risk of mortality (18)	Composite increased risk
Chronic Cardiac Disease	29%	14% (19)	2.07	1.31	2.71
Uncomplicated diabetes	19%	4.8% (20)	3.95	N/A	3.95
Chronic pulmonary disease excluding asthma	16%	4.5% (21)	3.56	1.19	4.2
Asthma	14%	8.3% (22)	2.15	1.19	2.55
Dementia	10%	1.3% (23)	7.69	1.39	6
Malignant neoplasm	9%	1.5% (24)	6.00	1.19	8.45
Rheumatological disorder	9%	0.8% (25)	11.25	N/A	11.25
Obesity (BMI>30kg/m^2)	38.5%	27.8%	1.38	1.37	1.90
Diabetes (with complications)	6%	1.2%	5.00	N/A	5

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Table 4 Suggested risk stratification tool

Risk factor	Indicator	Adjustment
Age	>50 >60 >70 >80	1 2 3 4
Sex at Birth	Female Male	0 1
Ethnicity	Caucasian Black African descent Indian Asian descent Other (including Mixed race)	0 2 1 1
Diabetes	(Type 1 or Type 2) uncomplicated (Type 1 or Type 2) complicated	1 2
Cardiovascular disease	Angina or previous MI and stroke intervention Heart failure	1 2
Pulmonary disease	Asthma Non-Asthma chronic pulmonary disease	1 2
Malignant neoplasm	Active malignancy Malignancy in remission	3 1
Rheumatological conditions	Active treated conditions	3

Interpretation	Score
Low Risk	<3
Medium Risk	3-5
High Risk	≥6

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Table 5. Mitigation Factors for Doctors

Factor	***Detail of procedure***
Hand Hygiene	Appropriate gloves use 20 seconds hand washing with soap
Respiratory Hygiene	Fluid resistant mask FFP3 mask for AGP Eye protection to reduce droplet transmission through lacrimal ducts
Mental health	Reduced duration of acute activity and Buddy system.
Social Distancing	A minimum of 2m (6.5 feet) or full PPE and remote working
Health Pre-habilitation	Risk Factors should be screened and mitigated in an Occupational Risk Assessment