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Development and presentation of an objective risk stratification tool for healthcare workers when dealing with the COVID-19 pandemic in the UK: risk modelling based on hospitalisation and mortality statistics compared with epidemiological data

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ABSTRACT

Objectives Healthcare workers have greater exposure to SARS-CoV-2 and an estimated 2.5-fold increased risk of contracting COVID-19 than the general population. We wished to explore the predictive role of basic demographics to establish a simple tool that could help risk stratify healthcare workers.

Setting We undertook a review of the published literature (including multiple search strategies in MEDLINE with PubMed interface) and critically assessed early reports on preprint servers. We explored the relative risk of mortality from readily available demographics to identify the population at the highest risk.

Results The 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, and people of black and minority ethnicity groups had higher susceptibility to both hospitalisation and mortality. *Comorbid disease*. Vascular disease, renal disease, diabetes and chronic pulmonary disease further increased risk. *Risk stratification tool*: A risk stratification tool was compiled using a white female <50 years with no comorbidities as a reference. A point allocated to risk factors was 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 with remote supportive roles.

Conclusions We generated a tool that provides a framework for objective risk stratification of doctors and healthcare professionals during the COVID-19 pandemic, without requiring disclosure of information that an individual may not wish to share with their direct line manager during the risk assessment process. This tool has been made freely available through the British Medical Association website and is widely used in the National Health Service and other external organisations.

Strengths and limitations of this study

► There is an increased risk of mortality in the clinical workforce due to effects of COVID-19.

► This article outlines a simple risk stratification tool that helps to quantify an individual's biological risk.

► This tool does not incorporate other external factors, such as high-risk household members or those at higher risk of mental health issues, that may require additional consideration when allocating clinical duties in an appropriate clinical domain.

► This population-based analysis did not explain the reason for the very high risk observed in black, Asian and minority ethnic healthcare workers, suggesting there are other issues at play that require addressing.

► The risk assessment tool presented continues to be tested and validated against primary care databases—the most up to date version will remain freely available at https://www.bma.org.uk/media/3820/bma-covid-19-risk-assessment-tool-february-2021.pdf.

The Health and Safety Executive mandates that all employers protect their employees from harm under the Management of Health and Safety at Work Regulations 1999. There are three key elements to this: identify what could cause the injury (the hazard), decide how likely that someone could be harmed and how seriously they are likely to be harmed (the vulnerability) and what actions can be taken to minimise this risk (the mitigation). In the current coronavirus pandemic, it is clear that COVID-19 is the agent that causes injury. The risk of harm is higher in

healthcare workers compared with the general population,[1] and thus action is required to minimise this risk. In the early phase of the pandemic, the Office of National Statistics reported medical practitioners had a 2.5-fold increase (95% CI, 1.5 to 4.3) in mortality compared with the average mortality from 2014 to 2018.[2] This compared with a 50% increased risk in the age-matched general population (HR, 1.5; 95% CI, 1.5 to 1.6). This trend was in keeping with observations in other countries of higher mortality among healthcare workers.[3–7]

While reasonable measures must be taken to protect all staff members from infection, individuals thought to be particularly vulnerable to infection may require modification of their practice. The Faculty of Occupational Medicine and National Health Service (NHS) Employers in England produced recommendations that all healthcare practitioners should receive an occupational risk assessment.[8 9] These frameworks were borne of the observation that certain ethnic groups appeared to be at higher risk than others[9] while recognising there are several other biological parameters, such as age, male sex, prior cardiovascular disease and diabetes, that were also associated with adverse outcomes. These predictors of hospitalisation, progression to intensive care units (ICUs) and ultimately death were reaffirmed in the Public Health England document.[10]

Despite the intention to improve risk assessment in healthcare settings, these frameworks failed to produce an objective tool to improve stratification across the healthcare system. The need for such a tool is highlighted by the disproportionate impact of COVID-19 on healthcare workers of black, Asian and minority ethnicity (BAME) descent. Up to 21 April 2020, 36% and 27% of the fatalities came from people of Indian Asian heritage and black African descent, respectively, despite those populations only representing 10% and 6% of the workforce. Existing data suggest that biological parameters do not account for all the increased risk, raising the possibility of cultural differences in self-assessment of risk or systemic challenges in modification of hazards for people of different ethnic background. Indeed, these cultural challenges have been proposed as a contributor to the increased risk in BAME populations.

Using published data on the demographics of those who have been hospitalised, and ultimately died, due to COVID-19 compared with the general population prevalence in these determinants, we have developed an objective risk stratification (ORS) tool. Creation of such an objective tool that can be applied equally and without favour to all healthcare practitioners allows biological risk to be evaluated and is used to reduce hazard.

METHODS
We reviewed the published literature (including multiple search strategies in MEDLINE with PubMed interface) and EMBASE and critically assessed early reports on medRxiv, a preprint server (https://www.medrxiv.org/) (date of last search: 21 April 2020).

Eligibility criteria
Studies were included according to the following criteria.

Search terms
COVID-19, Coronavirus, SARS-CoV2, Coronavirus AND mortality, hospitalisation.

Participants
As it had already been observed that there were differences in the impact of COVID-19 in different geographic locations and different socioeconomic circumstances, we limited the search to reports from the UK.

Outcomes
Given there are selection biases in testing for coronavirus, COVID-19 care and reporting, we predominantly explored the 'hard outcomes' of admission to the ICU and mortality. Although the occurrence of mild symptoms and asymptomatic disease may have an impact on the ability of health systems to function and on nosocomial spread, it would not cause significant long-term consequences and thus was not considered as an outcome.

Ethics statement
This project was based on secondary analysis of existing data; therefore, ethics approval was not required.

Information sources and search strategy
We searched the following electronic databases: MEDLINE, EMBASE and the preprint server medRxiv from inception to 22 April 2021. Only English-language articles were included. The reference lists of included reports were also searched for additional reports. 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. We reviewed the case reports and cohort studies and, where possible, the local demographics. Because of the urgency to improve risk stratification in the middle of the ongoing pandemic, reports were considered that otherwise would not have met the rigours of a systematic review. All reports were assessed for risk of bias (ROB) using the Cochrane ROB V.2.0 tool[11]; however, this assessment was used to inform the weighting given to the information contained there when being reviewed by the experts to form a consensus risk assessment tool.

The nature of the risk tool was the subject of several focus group meetings. The requirement was for it to be simple to complete, be objective such that it could stratify the vulnerability of exposure and not reveal personal information because it may be misused by 'line managers' after the pandemic. The latter requirement was a particular request from the BAME representatives to the focus groups, who feel that they are particularly vulnerable to workplace bullying.[12] This results in the requirement for a

single-page risk assessment tool that presents cumulative factors that could be completed ahead of a conversation with the designated manager and a clear stratification of vulnerability.

Risk of hospitalisation and mortality was analysed compared with population prevalence. Multivariate Cox regression modelling was used to estimate adjusted HR. Risk was normalised to a female aged 40–49 years, and an integer to approximate the impact of demographics, such as age,[13] ethnicity[14] and important comorbidities,[15] was assigned.

There are two principal sources of data: the Intensive Care National Audit and Research Centre (ICNARC) report that collated data from the national clinical audit covering all NHS adult, general intensive care and combined intensive care/high dependency units in England, Wales and Northern Ireland, plus some additional specialist and non-NHS critical care units, and the OpenSafely report that quantified a range of risk factors for death from COVID-19 based on primary care records.[16] Given these two principal sources of data, we collated and compared the risk of admission to intensive therapy unit (ITU) and mortality from the ICNARC study with the general population data.[17] Predictive risk modelling was used to predict the vulnerability of individuals.

This risk tool was standardised to the risk of mortality of a female under the age of 50 years. A point was then allocated for each approximate doubling in risk. Given the likely colinearity of multiple risk factors where risk was a greater multiple than 2, it was rounded down. As the purpose of this objective risk assessment tool is to supplement rather than supplant existing Public Health England recommendations, characteristics that warranted shielding according to the NHS Digital shielded patient list algorithm were discounted. Risk factors were only included in the derived objective risk assessment tool if they CI of their independent predictive role did not cross the line of unity (ie, p<0.05). Receiver operating characteristic curves were used to identify the scores that would best identify high risk (risk of admission to ITU or death) or moderate risk (risk of hospitalisation but no long-term complications).

Once a simplified risk tool was compiled, it was validated using the composite HRs derived from the OpenSafely platform report.[18] We evaluated the risk in 317 cases within a trust and stratified them into low, middle and high risk. Agreement between the objective risk assessment tool and the calculated HR was evaluated using Cohen's kappa coefficient for inter-rater agreement.

RESULTS

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 UK population of healthcare providers was questionable (online supplemental table

Table 1	Clinical demographics
Age group	**Mortality**
<50 years	1 (reference)
50–69 years	4.02 (95% CI, 2.88 to 5.63)
70–79 years	9.59 (95% CI, 6.89 to 13.3)
≥80 years	13.59 (95% CI, 9.79 to 18.85)
Sex at birth	
Proportion of admissions	
Male	60.2%
Female	39.8%
Mortality once admitted	
Male	1.2 (95% CI, 1.11 to 1.29)
Female	1 (reference)
Composite risk	
Male	1.96
Female	1 (reference)

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]
ISARIC, International Severe Acute Respiratory and Emerging Infection Consortium.

1). One point of agreement, however, was that multiple comorbidities appeared to confer cumulative risk. As a result, the development of a risk calculator was based exclusively on UK data, with multiple comorbidities being given additional weighting.

Clinician demographics
Age and sex
In all age groups, mortality was at least twice as high in men compared with women (table 1). Compared with those under the age of 50 years, in men mortality doubled in the age group of 50–59 years, quadrupled in the age group of 60–69 years and was 12 times higher in those aged above 70 years.

Ethnicity
People of non-white ethnic origin were at a higher risk of hospitalisation and mortality than the general population. Raw data suggested there was a 2-fold to 4-fold increased risk compared with the local population for COVID-19 compared with non-COVID-19 viral pneumonia over the previous 3 years .[19] This was, in part, explained by the premature onset of comorbidities that also conferred risk, such as type 2 diabetes, ischaemic heart disease and stroke.[20–23] After multivariate adjustment, however, some of this risk could not be accounted for with conventional risk factors, and therefore an ethnicity adjustment was included. This is most accentuated in people of black African descent where the risk was 2-fold elevated compared with those of white European descent. People of Indian Asian descent also had an approximately 50%

increased risk of hospitalisation compared with their European counterparts.

Socioeconomic status

For influenza, 25% of ICU admissions are people from the most deprived quintile compared with just 15% from the least deprived (online supplemental table 2). Once on ITU, however, there were only slight differences in mortality between people in the most deprived and least deprived status.

Comorbidities

There are multiple comorbid factors that are 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%) (online supplemental table 2).[24] These represented 16 749 patients: 7924 (47%) patients had no documented reported comorbidity. Although numerically not a large percentage of patients, those with active malignant neoplasms, chronic kidney disease or liver disease were between 3-fold and 5-fold increased risk of hospitalisation, respectively, compared with the prevalence in the general population. Although data were sparse, there was a suggestion that other conditions requiring long-term immunosuppressant therapy was similarly overrepresented by approximately 50% (data not shown). Similarly, dementia was associated with a significantly higher risk of both hospitalisation (~7.7 times increase) and mortality in hospital (39% increase) than the general population. There has been limited relevance for modifying clinical exposure, although it may be pertinent if using this tool to assess risk within the community. Contrary to many popular media reports, the increased risk of hospitalisation and mortality for people living with obesity was, in the first stages, accounted for by comorbidities such as diabetes, ischaemic heart disease and stroke. Beyond a body mass index of $35 \, \text{kg/m}^2$ (or $30 \, \text{kg/m}^2$ in people of Asian and black African descent), however, there was an independent predictive increased risk.

Generating an ORS tool

By considering each of the demonstrated associated factors for COVID-19 hospitalisation and subsequent mortality, a risk stratification tool was generated, which may be considered when allocating clinical individuals to standard or higher risk duties (table 2). The risk model attributes a point for every approximate doubling of risk compared with the reference population (HR ≥1.75 and ≤2.25). By adding the risk score from each category, it gives every individual a personal risk score that provides an estimate of their biological hazard. A high risk score was defined

When validating this tool against the 317 predefined cases in a single NHS trust, the outcomes of the ORS tool correlated well with absolute risk scores in the OpenSafely platform (Cohen's kappa, 0.76; SD, 0.071; p<0.0001;

Table 2 Suggested objective risk stratification tool for individuals not already identified as 'vulnerable' by the NHS Digital shielded patient list

Risk factor	Indicator	Adjustment
Age	>50	1
	>60	2
	>70	4
	>80	6
Sex at birth	Female	0
	Male	1
Ethnicity	White European	0
	Black African descent	2
	Indian Asian descent	1
	Filipino descent	1
	Other (including Mixed race)	1
Diabetes and obesity	(Type 1 or type 2) uncomplicated*	1
	(Type 1 or type 2) complicated*	2
	BMI ≥35 kg/m² (>30 kg/m² if of BAME descent)	1
Cardiovascular disease	Angina, previous MI, stroke or cardiac intervention	1
	Heart failure	2
Pulmonary disease	Asthma	1
	Non-asthma chronic pulmonary disease	1
	Either of the above requiring oral corticosteroids in the previous year	1
Malignant neoplasm	Active malignancy	3
	Malignancy in remission	1
CKD	CKD 3 or 4	2
	End-stage renal disease/ transplant	4
Chronic liver disease	Any active disease	3
Immunosuppressant therapy	Any indication	1

Interpretation	Score
Low risk	<3
Medium risk	3–5
High risk	≥6

*Complicated diabetes=presence of microvascular complications or HbA1c ≥64 mmol/mol.
BAME, black, Asian and minority ethnicity; BMI, body mass index; CKD, chronic kidney disease; MI, myocardial infarction; NHS, National Health Service; NHS, National Health Service.

table 3). A final validation was performed against the Public Health England document 'Disparities in the risk and outcomes of COVID-19'.[10] This demonstrated a similarly high level of agreement (Cohen's kappa, 0.81; SD, 0.063; p<0.0001).

Pregnancy

There are currently insufficient data to make any meaningful assessment about the risk of COVID-19 to either the mother or the unborn child. Early reports from

Table 3 Validation of the ORS tool compared with the OpenSafely Platform report.

	OpenSafely platform report			
	≤3-fold increased risk	3-fold to 6-fold increased risk	≥6-fold increased risk	Total number of subjects
ORS tool				
Score <3 PPV	208 91.6%	11	0	219
Score 3–5 PPV	19	57 77.0%	3	79
Score ≥6 PPV	0	6	13 81.3%	19
Total	227	74	16	317

Number of healthcare workers scoring low, medium and high risk in a validation exercise of the two tools using data from 317 individuals working in the healthcare system.
Cohen's kappa for agreement is 0.76; p<0.0001.
ORS, objective risk stratification; PPV, positive predictive value.

the UK and the USA suggest there is no risk to either; however these are based on small numbers.[25][26] Given the unknown risk to both parties, although pregnancy is not considered as a risk factor in its own right, we would recommend all people who are pregnant be regarded as high risk and offered the option to shield.

DISCUSSION

There are currently no reliable data for COVID-19-related deaths in healthcare 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 healthcare workers to generate a simplified biological risk stratification tool and made this freely available on the British Medical Association's website at https://www.bma.org.uk/media/3820/bma-covid-19-risk-assessment-tool-february-2021.pdf. This may serve to inform employers when allocating specific duties within the healthcare provision system to fulfil their duty of care to their employees.

There are three types of risk for medical staff. The first relates to their biology, the second to their environment and the third to the exposure. This tool evaluates the former to advise mitigation of the latter by stratifying individuals to lower, medium and higher risk. This biological risk assessment tool does not in any way replace the need for universal precautions with appropriate personal protective equipment (PPE). It should only be used to inform the need for modification of allocated duties to roles with little or no direct contact with patients, such as 'advice and guidance' services or virtual clinic provision. It incorporates and weights recognised risk factors. Many of these factors are predictable, such as age, gender and

pre-existing respiratory disease, all of which have been associated with many previous viral infections such as H1N1 influenza.

The importance of pre-existing cardiovascular disease and cerebrovascular disease is a novel observation for a respiratory disease. This may be due to the method of cellular invasion of SARS-CoV-2 using the ACE2 enzyme, an enzyme which is responsible for physiological vascular health responses to hypertension and obesity. It does not, however, explain the risk associated with diabetes,[27] nor does it account for the increased risk in some ethnic groups.

A recent finding showed that BAME individuals account for 63%, 64% and 95% of deaths in the Nurse, Healthcare Assistant and Doctor staff groups, respectively.[1] These figures are substantially higher than the proportional increase in BAME patients in UK ICUs (mortality of 18% compared with 12% in the general population).[19] Interestingly, our tool distinguished between people of black African descent and people of other non-European backgrounds, awarding a higher risk to those of West African descent. When validating the ORS tool against the OpenSafely report, however, the differential point award demonstrated similar overall predictive role in people of black African descent as other ethnicities. This is likely due to the different confounding disease profile in these populations. People of Indian subcontinent heritage develop additional risk factors such as diabetes and premature cardiovascular disease approximately 10 years earlier than the European counterparts. People of black African descent, however, are more likely to be affected by unmeasured risk factors such as haemoglobinopathies and systemic microvascular dysfunction.[28][29]

Application of the ORS tool

The primary role of any risk stratification tool is to provide a standardised approach to individual risk management by identifying those with the greatest adverse consequences from hazards.

Once individual risk is stratified, decisions regarding mitigating actions are required. Unfortunately, there remains uncertainty regarding the best action. The impact of recurrent exposure compared with high-risk exposures with high viral load or the environment of the clinical domain is uncertain. Similarly, the relative impact of different environments has not adequately been assessed. Currently, employees in front-line emergency and acute medical settings such as Emergency medicine, anaesthesia, respiratory medicine or gastroenterology may be considered at increased risk, as may be those who may need very close proximity with the patient such as Otorhinolaryngology (Ear Nose and Throat surgery, ENT) and ophthalmology. Some paradoxes have been observed. 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 contact,[30] suggesting that PPE provides effective protection. Conversely, those later in the disease

process with severe illness (particularly at the time of cytokine storm requiring high dependency care) may have reduced viral load and shedding,[31] therefore paradoxically having a lower potential to transmit infection compared with those at an early stage of the disease with no or relatively mild symptoms.

The ORS tool enables employers to decide when to exclude workers from working in presumed higher risk environments—even if workers do not wish to do so—or modify the nature of their duties to fulfil the employers' legal duty of care obligations to their workforce. It must be acknowledged that this tool is based purely on the 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 absolute risk, allowing healthcare 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. A limitation is that we only searched PubMed, EMBASE and preprint servers. There is an urgent need for high-quality research using individual-level data for healthcare workers that will allow full mediation analyses 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 coexist, and explore the disparity in BAME individuals between the deaths in general population and the healthcare workers . There are currently only limited observational data on COVID-19-related deaths in healthcare workers or doctors, again without full access to all potentially pertinent information. Since this tool was developed, there has been significant improvement in the epidemiological recording of the demographics of those who suffer from adverse consequences of COVID-19. The lead author has access to one of the key primary care record databases and uses these data for the regular observation and evaluation of the tool, which is currently on its fifth iteration. Importantly, this tool was, and continues to be, derived from and validated on UK data, and therefore may not be relevant in other countries; however, the methods employed here can be replicated in other healthcare settings.

Patient and public involvement

The primary target of this research was healthcare professionals, occupational health teams and medical managers. There was significant engagement with members of the British Medical Association—the trade union representing UK doctors—COVID-19 group and the staff members. Several members of this group are listed as coauthors, including the chair of the representative body. It is important to distinguish that these individuals are reporting personal views based on their branch of practice, and these are not necessarily the views of the Association.

Concluding remarks and key messages

As part of an employer's legal obligation under the Health and Safety legislation, all individuals are required to have a formal risk assessment. Although many organisations have advocated the need for individualised risk evaluation, there remains no standardised methodology for this assessment. Without a consistent approach to stratification, comparing individuals' personal risk within a department is difficult if not impossible. We have presented a robust scoring tool that allows comparisons and thus decisions to be made regarding the appropriate allocation of duties within a team. This also facilitates open discussion between staff who are being asked to work in patient facing areas and their team leaders so that they also understand their risks. All healthcare workers should wear appropriate PPE for any clinical examination or investigation on the basis that 20%–40% of infected patients, especially if less than 40 years of age, may be asymptomatic.[32] 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 given limited duties avoiding close contact such as in ENT, ophthalmology and dentistry. Those at the lowest risk may be assigned duties with more patient contact. Neither the ORS tool nor any other risk score negates the need for good PPE and training.

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Supplemental material

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Supplementary Table 1.
Co-morbidities associated with higher mortality in international studies

Author N in study	Guan 1590	Yang 46428	Zhou 191	Huang 41	Chen 99	Yang 52	Zhang 140	CDC 7162 USA	Onder 355 Italy	CSG 481 Italy
>1 comorbidity	25%		48%	32%	51%	40%		38%		
0 comorbidity										1.2%
1 comorbidity										23.5%
2 co-morbidity										26.6%
3+ comorbidities										48.6%
Hypertension	17%	17%	30%	15%			30%			74%
IHD	54%	5%	8%	15%	40%	10%		9%	30%	30%
Diabetes	8%	5%	19%	20%		9%	12%	11%	36%	34%
Cancer	1.1%				1%	4%			25%	19.5%
Cerebrovascular disease	2%					13%				11.2%
Respiratory disease		2.4%			1%		0%	9%		
COPD	1.5%					8%	1.4%			14%
Kidney disease	1.3%								3%	20%
Immunodeficiency	0.2%							4%		
Obesity								0.2%		

Supplementary Table 2 - Composite risk of contracting COVID-19 and mortality by pre-existing co-morbidity

	Prevalence in COVID-19[1]	Prevalence in population	Relative risk of contracting disease	Additional Risk of mortality (18)	Composite increased risk
Chronic Cardiac Disease	29%	14%[2]	2.07	1.31	2.71
Uncomplicated diabetes	19%	4.8%[3]	3.95	N/A	3.95
Chronic pulmonary disease excluding asthma	16%	4.5%[4]	3.56	1.19	4.2
Asthma	14%	8.3%[5]	2.15	1.19	2.55
Dementia	10%	1.3% [6]	7.69	1.39	6
Malignant neoplasm	9%	1.5%[7]	6.00	1.19	8.45
On Immunosuppressant therapy	9%	0.8% [8]	11.25	N/A	11.25
Obesity (BMI>35kg/m^2)	38.5%	27.8% [3]	1.38	1.37	1.90
Diabetes (with complications)	6%	1.2% [3]	5.00	N/A	5

Objective Risk Stratification tool for staff working with COVID-19

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