COVID-19 risk stratification tools should incorporate multi-ethnic age structures, multimorbidity and deprivation metrics for air pollution, household overcrowding, housing quality and adult skills

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Abstract

Background-Black Asian and Minority Ethnicity (BAME) patients account for 34% of critically ill COVID-19 patients despite constituting 14% of the UK population. Internationally, researchers have called for studies to understand the risk factors among ethnic subgroups. We explored the extent to which social determinants for health including individual Index of Multiple Deprivation (IMD) sub-indices are risk factors for presentation with multilobar pneumonia, Intensive Therapy Unit (ITU) admission and hospitalised outcomes disaggregated by BAME subgroup.

Methods-Multi-centre cohort study of hospitalised COVID-19 patients.

Results-BAME patients with pneumonia and low CURB65 scores (0-1) had higher mortality than Caucasians (22.6% vs.9.4%; p<0.001); Africans were at highest risk (38.5%; p=0.006), followed by Caribbean (26.7%; p=0.008), Indian (23.1%; p=0.007) and Pakistani (21.2%; p=0.004). Age, sex, cirrhosis, obesity, Charlson Comorbidity (CCI) scores, presentation with multilobar pneumonia and ITU admission were independent mortality risk factors. BAME subgroups were more likely to be admitted with higher CCI scores than age, sex and deprivation matched controls and from the highest IMD sub-indices of at least one deprivation form: Indoor Living Environment (LE), Outdoor LE, Adult Skills and Wider Barriers to Housing and Services. Admission from the highest sub-indices of these deprivation forms was associated with multilobar pneumonia on presentation and ITU admission.

Conclusions-BAME subgroups exhibit younger age structures resulting in CURB65 underscoring and disproportionate exposure to un-scored risk factors: sex, obesity, multimorbidity and deprivation. Household overcrowding deprivation, air pollution deprivation, housing quality deprivation and adult skills deprivation are associated with multilobar pneumonia on presentation and ITU admission. Risk tools need to reflect risk factors predominantly affecting BAME subgroups.

Key Messages

What is the key question?
To what extent do social determinants for health, including Index of Multiple Deprivation (IMD) sub-indices with indicators for household overcrowding, housing quality, air pollution and adult skills deprivation determine presentation with multilobar pneumonia, Intensive Therapy Unit (ITU) admission and outcomes among hospitalised COVID-19 patients stratified by Black Asian and Minority Ethnicity (BAME) subgroup?

What is the bottom line?
BAME patients presenting with COVID-19 pneumonia and low CURB65 scores (0-1) had higher mortality than Caucasians; BAME patients exhibit younger age structures resulting in CURB65 underscoring and disproportionate exposure to unscored risk factors: sex, obesity, multimorbidity and deprivation from regions of highest household overcrowding deprivation, air pollution deprivation, housing quality deprivation and adult skills deprivation.

Why read on?
Understanding the risk factors for presentation with multilobar pneumonia, ITU admission and mortality among individual BAME subgroup profiles is essential for the identification of patients at risk of deterioration, supporting triage to the appropriate level of care and informing the development of clinical risk stratification tools.

Introduction

Data published by the Intensive Care National Audit and Research Centre (ICNARC) shows that Black Asian and Minority Ethnicity (BAME) patients account for 34% of critically ill patients with SARS-CoV-2 infection (COVID-19) despite constituting 14% of the UK population. (1) Internationally researchers have called for studies to explain the increased deterioration among BAME subgroups. (2) Understanding the risk factors is essential for informing the development of risk stratification tools which triage patients to the appropriate level of care.

A recent study of COVID-19 pneumonia patients (n=279) suggests that the CURB65 tool, validated solely in community acquired pneumonia, is a potentially unreliable risk stratification tool for COVID-19 pneumonia despite its’ widespread use in clinical practice. (3) Studies have not thus far explored the resilience of CURB65 for risk stratifying COVID-19 pneumonia among BAME subgroups. Traditional clinical training has reinforced that the unmodifiable risk factor of age predisposes to adverse outcomes with little regard to epidemiological multi-ethnic age structures. BAME subgroups have younger age structures (4) which predispose to a lower CURB65 score and are susceptible to different underlying clusters of disease.

Furthermore, BAME patients are more likely than Caucasians to be hospitalised with COVID-19 from the most deprived IMD regions. (5) UK data published by the Office for National Statistics (ONS) shows higher age-standardised mortality rates for COVID-19 in the most deprived IMD areas (3.1 deaths per 100,000 patients) compared to the least deprived (1.4 deaths per 100,000) between 1st March 2020 and 31st July 2020. (6) However, studies have not yet explored individual IMD sub-indices as risk factors for presentation with multilobar pneumonia, Intensive Therapy Unit (ITU) admission and completed hospitalised episode outcomes. The IMD incorporates seven weighted deprivation sub-domains: Income, Employment, Health, Crime, Barriers to Housing and Services (BHS), Living Environment (LE) and Education, Skills and Training (EST). (7) BHS, LE and EST sub-domains each have two sub-indices. BHS sub-indices include (a) Geographical barriers, an indicator of proximity to local services, and (b) Wider BHS which contains an indicator for household overcrowding. LE sub-indices include (a) Indoor LE which has an indicator for housing quality and (b) Outdoor LE which is an indicator for air pollution. EST sub-indices include: (a) Children and Younger People’s education attainment and (b) Adult Skills which contains indicators for adult qualifications and English language proficiency. (8)
Understanding these risk factors is invaluable for informing the development of risk stratification tools which reflect risk factors to which BAME subgroups are potentially disproportionately predisposed.

This multi-centre study aims to test resilience of the CURB65 score in identifying patients at risk of deterioration disaggregated by BAME subgroup and explore the extent to which social determinants of health, including IMD sub-indices with indicators for household overcrowding, air pollution, housing quality and adult skills deprivation, act as risk factors for presentation with multilobar pneumonia, ITU admission and adverse outcomes among hospitalised COVID-19 patients disaggregated by BAME subgroup.

**Methods**

**Design and setting**

A multi-centre cohort study of hospitalised COVID-19 patients was performed to explore social determinants of health, including IMD sub-indices, as risk factors for presentation with multilobar pneumonia, ITU admission and completed hospitalised episode outcomes.

**Patient population**

COVID-19 patients (>16 years old) admitted to 4 hospitals across the West Midlands, University Hospitals of Birmingham, between 1st December 2019 and 1st September 2020 were included. Diagnosis was confirmed by PCR analysis of a combined nose and throat swab in accordance with Public Health England guidance. (9)

**Patient management**

See online supplement 1.

**Data collection and scoring analysis**

Data collected from the hospital informatics system included: demographics (ethnicity, age, postcode), admission details, comorbidities, clinical metrics (observations, blood tests), imaging, ITU admission details and completed hospitalised episode outcomes (discharge or death). Chest X-rays were reported by radiologists within 12 hours of being undertaken.

**IMD**

IMD sub-domains and sub-indices are detailed above. The IMD categorises deprivation metrics by postcode on a scale of 1 to 10 (most to least deprived centiles nationally). Detailed descriptions of IMD metrics are published by the UK Ministry of Housing, Communities and Local Government. (8) Deprivation metrics were derived by patient postcode. (8)

**Charlson Comorbidity Index (CCI)**

CCI is a validated tool quantifying comorbidity burden and corresponding 1 year mortality risk. (10)

**CURB65**

For patients presenting with pneumonia, severity was scored using CURB65 which determines 30-day mortality risk based upon: presentation with new onset confusion, urea (>7mmol/L), respiratory rate (>30 breaths/minute), blood pressure (<90mmHg systolic or £60mmHg diastolic) and age (>65 years). (11)

**Statistical Analysis**

Baseline characteristics were presented as mean and standard deviation (SD) for continuous variables and median and interquartile range (IQR) for non-parametric data. Normality was assessed by Shapiro-Wilk. For categorical and ordinal variables with non-parametric distribution, Fisher's exact test and Mann Whitney U test were used respectively for comparisons between two groups. Multivariate analysis to predict mortality was performed using stepwise logistic regression with conservative criteria for entry or exit from the model of 0.1. Factors found to be significant in univariate analysis were included as independent variables. The Hosmer and Lemeshow goodness-of-fit test was performed to evaluate the adequacy of the logistic regression model. Matched case-control analyses were implemented to explore underlying multimorbidity among BAME subgroups; controls were Caucasians matched by age, gender and deprivation. Statistical analyses were carried out using SPSS Statistics V.24 and GraphPad Prism 8.

**Ethics statement**

Data were entered anonymously in accordance with national and local audit guidance. Health Research Authority (HRA) guidance was followed and ethical approval was not required based on the HRA Decision tool (Online Supplement 2).

**Results**

**Included participants**

3671 consecutive patients were eligible for inclusion. 716 patients did not meet inclusion criteria due to: ongoing hospitalisation on 1st September 2020 (n=55), age <16 (n=22), attendance as an elective admission (n=371) or attendance without admission (n=267). Of these patients (n=2955), those without
listed postcodes (n=301) or postcodes not returning deprivation metrics (n=8) could not be included in the analysed group (n=2646). Figure 1 shows the CONSORT diagram.

Study population

The study population is outlined in table 1. The median age of all patients was 76.0 (24.0). Males (54.8%) were hospitalised more than females (45.2%).

Hospitalised admissions by deprivation sub-index are depicted in figure 2 and ITU admissions by deprivation sub-index are depicted in figure 3. The proportion of patients admitted to hospital from the highest (sub-indices 1 and 2) deprivation forms were as follows: Wider BHS (59.0%), Adult Skills (43.6%), Indoor LE (42.3%) and Outdoor LE (56.5%). The proportions of BAME vs Caucasian patients hospitalised from the highest (sub-indices 1 and 2) deprivation forms was as follows: Wider BHS (81.7% vs 50.2%), Adult Skills (65.8% vs. 35.1%), Indoor LE (54.6% vs. 37.5%) and Outdoor LE (81.5% vs. 46.9%). BAME patients were more likely than Caucasians to be admitted to the aforementioned deprivation forms, present with multi-lobar pneumonia (OR 2.465(2.057-2.945); p<0.001) and require ITU admission (OR 2.823(2.219-3.611); p<0.001) (Online Supplement 3).

Participant Characteristics

<table>
<thead>
<tr>
<th>Table 2: A table showing participant characteristics including: age, gender, ethnicity, ITU admission, mortality and discharge</th>
</tr>
</thead>
</table>

Admission from highest deprivation sub-indices increases the risk of presentation with multilobar pneumonia

Patients were more likely to present with radiological multilobar pneumonia if domiciled from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 1.664(1.4229-1.946); p=0.049), Indoor LE (OR 1.537(1.313-1.791); p<0.0001), Outdoor LE (OR 1.764(1.510-2.060); p=0.001) and Adult Skills (OR 1.423(1.138-1.829); p=0.003) compared with patients admitted from all other respective IMD sub-indices (figure 4a). Patients presenting with multilobar pneumonia were at increased risk of ITU admission (OR 4.931(3.684-6.600), p=0.000) and mortality (age and sex adjusted) (OR 2.200(1.842-2.629); p=0.000) (figure 4a).

Admission from highest deprivation sub-indices increases the risk of ITU admission

Patients were more likely to be admitted to ITU if admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 1.282(1.002-1.640); p=0.0480), Indoor LE (OR 1.306(1.030-1.656); p=0.028), Outdoor LE (OR 1.485(1.160-1.901); p=0.002) and Adult Skills (OR 1.443(1.138-1.829); p=0.002) compared with patients admitted from all other respective IMD sub-indices (figure 4b). Age and sex adjusted mortality was higher among patients admitted to ITU (OR 3.510(2.643-4.662); p=0.000) (figure 4b).

Risk factors for mortality

BAME patients with pneumonia and low CURB65 scores (0-1) had higher mortality than Caucasians (22.6% vs.9.4%; p<0.001); Africans were at highest risk 38.5% (OR 6.047(2.129-18.890); p=0.006), followed by Caribbean 26.7% (OR 3.518(1.533-8.474); p=0.008), Indian 23.1% (OR 2.903(1.433-6.068); p=0.007) and Pakistani 21.2% (OR 2.561(1.419-4.656); p=0.004). Table 2 disaggregates CURB65 scores by ethnic subgroup.
Univariate analyses identified that mortality was associated with: sex (OR 1.4001(1.188-1.400); p=0.000), higher CCI scores (p<0.001), comorbidities: obesity (OR 3.317(2.773-3.960); p=0.000), hypertension (1.225(1.039-1.446); p=0.018), ischaemic heart disease (IHD) (OR 1.335(1.081-1.655); p=0.009), heart failure (OR 1.380(1.028-1.844); p=0.032), peripheral vascular disease (PVD) (OR 1.225(1.039-1.446); p=0.018), COPD (OR 1.336(1.028-1.730); p=0.034), type 2 diabetes mellitus (T2DM) (OR 1.209(1.010-1.448); p=0.041), cirrhosis (4.395(1.786-10.820); p=0.009), chronic kidney disease (CKD) (OR 1.437(1.028-1.808); p=0.002) (figure 5), multimorbidity: ≥ 2 comorbidities (OR 2.0260(1.593-2.576); p<0.0001) and ≥ 4 comorbidities (OR 1.646(1.380-1.964); p<0.0001), multi-lobar pneumonia on presentation (OR 2.13(1.772-2.57); p=0.000) and ITU admission (OR 3.510(2.643-4.662); p=0.000).

Univariate analyses also identified that mortality (age and sex adjusted) was associated with Pakistani (OR 1.340(1.012-1.774); p=0.041) and African (OR 2.415(1.040-5.607); p=0.040) ethnicity although multivariate analyses found ethnicity not to be an independent mortality risk factor.

Stepwise multiple regression, including the above variables, identified 7 variables which were independently associated with mortality: age, sex, cirrhosis, obesity, CCI score, presentation with multi-lobar pneumonia and ITU admission (table 3). As demonstrated below, BAME patients were more likely than Caucasians to exhibit 5 of 7 variables: (1) male, (2) obesity, (3) higher CCI scores than age, sex and deprivation matched Caucasian controls, (4) presentation with multi-lobar pneumonia and (5) ITU admission.

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Number of patients presenting with pneumonia</th>
<th>Multi-lobar pneumonia</th>
<th>ITU admission</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>1212</td>
<td>427 (38.5)</td>
<td>57 (22.6)</td>
<td>16 (11.3)</td>
</tr>
<tr>
<td>BAME</td>
<td>529</td>
<td>252 (60.3)</td>
<td>57 (22.6)</td>
<td>16 (11.3)</td>
</tr>
<tr>
<td>Pakistani</td>
<td>245</td>
<td>18 (122)</td>
<td>46 (28.2)</td>
<td>8 (74.0)</td>
</tr>
<tr>
<td>Indian</td>
<td>77</td>
<td>12 (23.1)</td>
<td>9 (12.3)</td>
<td>1 (11.1)</td>
</tr>
<tr>
<td>Caribbean</td>
<td>69</td>
<td>30 (48.4)</td>
<td>19 (30.6)</td>
<td>5 (26.3)</td>
</tr>
<tr>
<td>African</td>
<td>16</td>
<td>5 (38.5)</td>
<td>6 (37.5)</td>
<td>1 (15.4)</td>
</tr>
<tr>
<td>Chinese</td>
<td>12</td>
<td>5 (100.0)</td>
<td>5 (100.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>6</td>
<td>5 (100.0)</td>
<td>5 (100.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Mixed</td>
<td>15</td>
<td>8 (76.9)</td>
<td>2 (25.0)</td>
<td>1 (50.0)</td>
</tr>
<tr>
<td>Any other non-Caucasian</td>
<td>83</td>
<td>97 (64.6)</td>
<td>9 (17.6)</td>
<td>3 (25.0)</td>
</tr>
</tbody>
</table>

| Unspecified | 15 | 9 (60.0) | 0 (0.0) | 5 (33.3) | 1 (20.0) | 4 (66.7) | 0 (0.0) | 1 (100) |

To understand the risk factors for presentation with multi-lobar pneumonia, ITU admission and mortality affecting each ethnic group, BAME subgroups were disaggregated.

Ethnicity: taking a closer look

Demographics: age structures, sex and ethnicity

BAME patients were more likely to be male (OR 1.199(1.009-1.426); p=0.042) and present age≥65 (OR 4.846(4.020-5.843); p<0.001) than Caucasians. Caribbean and Caucasian subgroups presented older (median age≥65) whilst Indian, Pakistani, African, Chinese and Bangladeshi subgroups presented younger (median age<65); this is consistent with UK population age structures. (4)
Comorbidity, multimorbidity and ethnicity

Comorbidities by ethnic subgroup are shown in Table 4 and Online Supplement 4. BAME patients were more likely to be obese (OR 1.640; 1.363-1.975; p=0.001). Caucasians were more likely to have cirrhosis (OR 7.778; 1.447-81.10; p=0.014). Although the overall proportion of Caucasians with multimorbidity appears higher than BAME subgroups (Table 4), CCI scores in every BAME subgroup were higher than age, sex and deprivation matched Caucasian controls (Table 5) and the average number of comorbidities among African, Pakistani and Caribbean patients was higher than age and sex matched Caucasian controls (Table 5).

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>Caucasian</th>
<th>BAME</th>
<th>Indian</th>
<th>Caribbean</th>
<th>African</th>
<th>Chinese</th>
<th>Bangladeshi</th>
<th>Indian</th>
<th>Any other ethnic group</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYH</td>
<td>182 (72.4)</td>
<td>215 (80.4)</td>
<td>182 (70.3)</td>
<td>215 (75.9)</td>
<td>182 (69.4)</td>
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<td>182 (69.4)</td>
<td>215 (75.9)</td>
<td>182 (69.4)</td>
</tr>
<tr>
<td>Hypertension</td>
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<td>182 (70.3)</td>
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<td>182 (69.4)</td>
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<td>182 (69.4)</td>
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<tr>
<td>Hypertensive</td>
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<td>143 (48.3)</td>
<td>122 (47.4)</td>
<td>143 (48.3)</td>
<td>122 (47.4)</td>
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<td>122 (47.4)</td>
<td>143 (48.3)</td>
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<tr>
<td>Diabetes</td>
<td>38 (13.3)</td>
<td>100 (31.3)</td>
<td>38 (13.3)</td>
<td>100 (31.3)</td>
<td>38 (13.3)</td>
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<td>38 (13.3)</td>
<td>100 (31.3)</td>
<td>38 (13.3)</td>
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<tr>
<td>CCI</td>
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<td>308 (51.8)</td>
<td>215 (75.9)</td>
<td>193 (67.3)</td>
<td>182 (69.4)</td>
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<td>Peripheral Vascular Disease</td>
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<td>99 (21.3)</td>
<td>94 (20.4)</td>
<td>99 (21.3)</td>
<td>94 (20.4)</td>
<td>99 (21.3)</td>
<td>94 (20.4)</td>
<td>99 (21.3)</td>
<td>94 (20.4)</td>
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<tr>
<td>Stroke</td>
<td>211 (48.5)</td>
<td>312 (49.8)</td>
<td>211 (48.5)</td>
<td>312 (49.8)</td>
<td>211 (48.5)</td>
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<td>211 (48.5)</td>
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<td>211 (48.5)</td>
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<tr>
<td>Obese</td>
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<td>305 (55.7)</td>
<td>251 (51.0)</td>
<td>305 (55.7)</td>
<td>251 (51.0)</td>
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<tr>
<td>Cardiovascular disease</td>
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<td>246 (41.7)</td>
<td>146 (31.3)</td>
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<td>146 (31.3)</td>
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<tr>
<td>COPD</td>
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<td>202 (35.9)</td>
<td>191 (39.2)</td>
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<td>191 (39.2)</td>
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<td>191 (39.2)</td>
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<tr>
<td>Infections</td>
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<tr>
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<td>Heart Failure</td>
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<td>19 (4.0)</td>
<td>25 (4.3)</td>
<td>19 (4.0)</td>
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<td>14 (2.9)</td>
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<tr>
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<td>50 (10.1)</td>
<td>66 (11.2)</td>
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<td>66 (11.2)</td>
<td>50 (10.1)</td>
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<tr>
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<td>26 (5.3)</td>
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<td>32 (5.5)</td>
<td>26 (5.3)</td>
</tr>
</tbody>
</table>
| Table 4: A table representing underlying comorbidities and multimorbidity among hospitalised COVID-19 positive patients by ethnic subgroup: disaggregating BAME.
Deprivation sub-indices, presentation with multilobar pneumonia, ITU admission and ethnicity

Admission from sub-indices of highest deprivation (sub-indices 1 and 2): BHS, Wider BHS, LE, Outdoor LE, Adult Skills deprivation were associated with multilobar pneumonia on presentation and ITU admission, which are in themselves independent mortality risk factors. Table 6 disaggregates the proportion of admissions from the respective deprivation forms by ethnicity.

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>N</th>
<th>Admission from regions of highest BHS deprivation</th>
<th>Admission from regions of highest Wider BHS deprivation</th>
<th>Admission from regions of highest LE deprivation</th>
<th>Admission from regions of highest Outdoor LE deprivation</th>
<th>Admission from regions of highest Adult Skills deprivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAME</td>
<td>722</td>
<td>542 (74.2)</td>
<td>580 (81.7)</td>
<td>506 (71.3)</td>
<td>388 (54.4)</td>
<td>578 (82.5)</td>
</tr>
<tr>
<td>Indian</td>
<td>95</td>
<td>84 (59.5)</td>
<td>82 (61.6)</td>
<td>83 (64.3)</td>
<td>89 (67.7)</td>
<td>90 (61.9)</td>
</tr>
<tr>
<td>Pakistani</td>
<td>326</td>
<td>260 (79.7)</td>
<td>263 (80.7)</td>
<td>202 (62.0)</td>
<td>240 (73.0)</td>
<td>266 (81.5)</td>
</tr>
<tr>
<td>Caribbean</td>
<td>205</td>
<td>108 (52.8)</td>
<td>76 (47.2)</td>
<td>15 (63.6)</td>
<td>9 (57.6)</td>
<td>15 (63.6)</td>
</tr>
<tr>
<td>Mixed</td>
<td>22</td>
<td>15 (75.6)</td>
<td>12 (54.5)</td>
<td>8 (36.4)</td>
<td>14 (60.9)</td>
<td>16 (72.7)</td>
</tr>
<tr>
<td>Total</td>
<td>1311</td>
<td>741 (56.5)</td>
<td>785 (59.5)</td>
<td>595 (45.5)</td>
<td>508 (38.8)</td>
<td>572 (43.7)</td>
</tr>
</tbody>
</table>

Table 6: Proportion of patients admitted from regions of highest deprivation: BHS, Wider BHS, LE, Outdoor LE and Adult Skills

Indian

Indian patients were more likely than Caucasians to be admitted from regions of highest (sub-indices 1 and 2) Outdoor LE deprivation (OR 2.623(1.680-4.072); p<0.001), present with multilobar pneumonia (OR 3.195(2.032 to 5.205); p<0.001) and require ITU admission (OR 3.181(1.906 to 5.309); p<0.001) (figure 6a).

Pakistani

Pakistani patients were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 8.796(6.127-12.760); p<0.001), Outdoor LE (OR 9.103(6.392-13.080); p<0.001), Indoor LE (OR 2.714(2.136-3.458); p<0.001), Adult Skills (OR 8.195(6.099-11.02); p<0.001), present with multilobar pneumonia (OR 2.566(2.005-3.282); p<0.001) and require ITU admission (OR 2.769(2.021-3.793); p=0.000) (figure 6b).

African

Africans were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 4.161(1.579-10.170); p=0.002), Outdoor LE (OR 3.067(1.307-7.716); p<0.009), Adult Skills (OR 6.161(2.500-14.570); p<0.001), present with multilobar pneumonia (OR 3.547(1.511-8.924); p=0.004) and require ITU admission (OR 4.847(2.075-11.322); p=0.000) (figure 6c).

Caribbean

Table 5: A table representing Charlton Comorbidity Index (CCI) scores among patients of constituent BAME ethnic subgroups in comparison with matched controls by: a) Age and Gender, b) Age, Gender and Outdoor LE deprivation, c) Age Gender and Indoor LE deprivation, d) Age, Gender and Adult Skills deprivation.
Caribbean patients were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 5.128(3.044-8.653); p<0.001), Indoor LE (OR 1.833(1.247-2.712); p=0.003), Outdoor LE (OR 6.286(3.662-11.050); p<0.001), Adult Skills (OR 1.884(1.278-2.779); p=0.002) and present with multilobar pneumonia (OR 1.613(1.091-2.404); p=0.020) (figure 6d). Caribbean patients were not more likely to require ITU admission (p>0.05).

Chinese

Chinese patients were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 4.293(1.270-14.200); p=0.021), present with multilobar pneumonia (OR 3.921(1.260-11.160); p=0.020) and require ITU admission (OR 6.544(2.348-18.237); p=0.000) (figure 6e).

Bangladeshi

Bangladeshi patients were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 4.458(1.109-20.630); p=0.037), Outdoor LE (OR 5.085(1.265-23.530; p=0.001) and Adult Skills (OR 3.235(1.041-9.912); p=0.048) although they were not more likely to present with multilobar pneumonia or require ITU admission (figure 6f).

Mixed

Mixed ethnicity patients were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 3.368(1.295-8.373); p=0.016) and Adult Skills (OR 4.929(2.005-12.070); p=0.001) although they were not more likely to present with multilobar pneumonia or require ITU admission (figure 6g).

Any other non-Caucasian ethnic group

Patients of any other non-Caucasian ethnicity were more likely than Caucasians to be admitted from regions of highest deprivation (sub-indices 1 and 2): Wider BHS (OR 3.239(2.069-5.056); p=0.001), Indoor LE (OR 1.966(1.335-2.852); p=0.001), Outdoor LE (OR 3.195(2.088-4.948); p=0.001), Adult Skills (OR 2.517(1.711-3.707); p=0.001), present with multilobar pneumonia (OR 2.838(1.878-4.253); p<0.001) and require ITU admission (OR 3.819(2.428-6.006); p=0.000) (figure 6h).

Discussion

Among hospitalised COVID-19 patients presenting with pneumonia and lower CURB65 scores (0-1), mortality was higher among BAME patients than Caucasians; Africans were at highest risk, followed by Caribbean, Indian and Pakistani. BAME subgroups were more likely to be admitted with higher CCI scores than age, sex and deprivation matched controls and from the highest IMD sub-indices of at least one deprivation form. Patients admitted from regions of highest Indoor LE deprivation, Outdoor LE deprivation, Wider BHS deprivation and Adult Skills deprivation were more likely to present with multilobar pneumonia and require ITU admission, which are in themselves independent mortality risk factors. This may explain the higher ITU admissions among BAME patients reported by ICNARC (1) and ONS data reporting higher age standardised mortality rates among patients in the most deprived IMD areas. (6) CCI scores, presentation with multi-lobar pneumonia, ITU admission, age, sex, cirrhosis and obesity were independent risk factors for mortality. BAME patients were more likely than Caucasians to exhibit 5 of these 7 risk factors.

A recent study of COVID-19 pneumonia patients (n=279) found that, as a largely physiological assessment, CURB65 is an unreliable mortality risk tool in COVID-19 pneumonia. (3) CURB65 mortality risk does not take account of hidden risk factors which appear to disproportionately affect BAME subgroups including: male, obesity, multimorbidity, presentation with multilobar pneumonia, household overcrowding, air pollution, housing quality and adult skills deprivation. Furthermore, national epidemiological data shows younger age structures among BAME subgroups which are also reflected in this study and which potentially predispose to an underscored CURB65 among BAME subgroups resulting in possible triage to an inappropriate level of care whilst clinicians are left falsely reassured regarding the severity of presentation and risk of deterioration.

This study finds that air pollution deprivation increases the odds of presentation with radiological multilobar pneumonia and ITU admission among COVID-19 patients. Pollutants compromise the host’s immune response against invading pathogens in the respiratory tract. (12) Chronic exposure to nitrogen dioxide and sulphur dioxide concentrations are associated with incidence of pneumonia (13) whilst particulate matter increases the activity of angiotensin-converting enzyme 2 receptors on cell surfaces (14), thus enhancing COVID-19 uptake by the lungs. BAME patients are more likely than Caucasians to be exposed to chronic air pollution on account of residing in regions of highest air pollution deprivation. (15) In this study all BAME subgroups apart from Chinese and Mixed were more likely than Caucasians to be admitted from regions of highest air pollution deprivation. Minimising air pollution deprivation inequalities is essential in reducing the disease burden of community acquired pneumonia (16) including COVID-19.

Furthermore, this study identifies household overcrowding deprivation and poor housing quality as potential risk factors for presentation with radiological multilobar pneumonia and ITU admission among COVID-19 patients. BAME subgroups are more likely than Caucasians to live in the most overcrowded and poorest quality housing. (15) The UK Biobank study has reported that patients with a COVID-19 positive test were more likely to live in crowded households (17) and it is well established that household overcrowding and housing quality failing to meet the Decent Homes Standard are associated with a higher incidence of non-COVID-19 pneumonia and increased risk of disease transmission. (18) Minimising household overcrowding and improving housing quality is essential for limiting the exposure to and spread of toxigenic species including bacteria, fungal and viral pathogens. (19)
Moreover, this study finds that adult skills deprivation including limited English language proficiency and low adult qualifications are potential risk factors for presentation with radiological multilobar pneumonia and ITU admission. Coronaviruses cause pneumonia which gradually progresses to further lung zones between 2 to 14 days. (20) It is possible that the predominantly English language messaging may have contributed to later presentation in patients from regions of highest adult skills deprivation. In this study, Caribbean, Pakistani, African, Bangladeshi, Mixed and any other non-Caucasian ethnic subgroups were more likely than Caucasians to be admitted from regions of highest adult skills deprivation. Minimising education inequalities including by exploring strategies designed to widen access to and boost engagement with health messaging is essential for enhancing compliance with infection, prevention and control measures and ensuring timely presentation.

Patients with obesity, hypertension, IHD, heart failure, CKD, PVD, T2DM, cirrhosis and CKD were at increased risk of mortality. The UK’s Chief Medical Officer has highlighted that comorbidities and the proportion of patients with multimorbidity is rising (21) presenting a challenge to the medical profession including within acute and long-term hospital settings (21-22). This study finds that obesity and multimorbidity are independent mortality risk factors. BAME patients were more likely to present with obesity. CCI scores among every BAME subgroup were higher than Caucasian controls matched by age, sex, Wider BHS deprivation, Outdoor LE deprivation, Indoor LE deprivation and Adult Skills deprivation. Furthermore, the multimorbidity burden among African, Caribbean and Pakistani patients was higher compared with age and sex matched Caucasian controls which may contribute an explanation towards the higher mortality among these subgroups despite low CURB65 scores (0-1).

This study included hospitalised COVID-19 patients within four hospitals across the West Midlands, although these constitute one of the UK’s largest NHS Trusts. It did not analyse COVID-19 patients who were not hospitalised or who died in the community. Future studies need to relate these findings with populations from other urban cities and rural regions with this level of granularity to inform national strategic planning.

**Conclusion**

Household overcrowding, air pollution, housing quality and adult skills deprivation are potential hidden risk factors for presentation with radiological multilobar pneumonia and ITU admission, which are themselves independent risk factors for mortality. BAME subgroups are more likely to be admitted from the most deprived sub-indices of at least one of these deprivation forms and with higher Charlson Comorbidity (CCI) scores than age, sex and deprivation matched Caucasian controls; multimorbidity is another independent risk factor for mortality.

BAME subgroups exhibit younger age structures resulting in potential CURB65 underscoring and disproportionate exposure to unscored risk factors of sex, obesity, multimorbidity and deprivation resulting in potential triage to an inappropriate level of care and clinicians left falsely reassured regarding the severity of presentation and risk of deterioration.

Consideration of multi-ethnic age structures, sex, body mass index, CCI score, chest X-ray imaging and deprivation sub-indices on admission supports clinicians in stratifying high risk patients. COVID-19 clinical risk stratification tools need to be developed to account for risk factors to which BAME subgroups are predominantly exposed. This will enable the early identification of patients at risk of deterioration and ensure triage to an appropriate level of care.

These findings have urgent implications for supporting front line clinical decisions and informing wider pandemic strategic planning. Future studies should explore these risk factors among non-COVID19 patients presenting to hospital.

**List Of Abbreviations**

- **BAME**: Black, Asian and Minority Ethnic group
- **BHS**: Barriers to Housing and Services
- **CCI**: Charlson Comorbidity Index (CCI)
- **CAP**: Community Acquired Pneumonia
- **COVID-19**: SARS-COV-2 virus infection
- **CKD**: Chronic Kidney Disease
- **EST**: Education Skills and Training
- **HRA**: Health Research Authority
- **IHD**: Ischaemic heart disease
- **IMD**: Index of Multiple Deprivation Score
- **IQR**: Interquartile range
- **ITU**: Intensive therapy unit (intensive care unit)
- **LE**: Living Environment
- **PVD**: Peripheral Vascular Disease
Declarations

Ethics approval and consent to participate
All data were entered by the Local Clinical Care Team in anonymized fashion without linkage to any patient identifiers in line with national and local audit guidance. In the UK Health Research Authority guidance was followed and ethical approval was not required. Ethics was not required based on the Health Research Authority Decision tool (Online Supplement 2).

Consent for publication
Not applicable

Availability of data and materials
All data relevant to the study are included in the article or uploaded as supplementary information

Competing interests
The authors declare that they have no competing interests

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Authors' contributions
MS collected data, undertook data analysis, designed this study and wrote this paper. MS, BS, CRM, JV, DT, DD, WC made substantial contributions to the conception, design of the work and supported data interpretation. MS, BS, CRM, JV, DP, SL, DD, DT, WC revised the final manuscript. All authors contributed to and approved the final version of the manuscript.

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Figures
Figure 1

A CONSORT diagram showing participants assessed for eligibility, the inclusion criteria and the final number of participants included. 3671 consecutive patients were assessed for eligibility for inclusion into this study. 716 patients were excluded on account of having not met the inclusion criteria due to: ongoing hospitalisation on 1st September 2020 (n=55), age <18 (n=22), attending hospital as an elective admission (n=371) or attending hospital without admission (n=267). Patients eligible for inclusion in this study (n=2955) were reviewed; patients without listed postcodes (n=301) or postcodes not returning deprivation metrics using the UKMCG English indices postcode look up tool (n=8) could not be included in the analysed group (n=2646).
Figure 2

Population pyramid distributions of hospitalised COVID-19 positive patients: (a) Index of Multiple Deprivation (IMD) distribution in the West Midlands population in comparison with the study population, (b) Wider BHS deprivation sub-index distribution and adult skills deprivation sub-index distribution in the study population, (c) Indoor LE deprivation sub-index and Outdoor LE deprivation sub-index distribution in the study population.
Figure 3

Population pyramid distributions of COVID-19 positive patients admitted to ITU from regions of (a) Outdoor Living Environment deprivation, (b) Indoor Living Environment deprivation, (c) Wider Barriers to Housing and Services deprivation, (d) Adult Skills deprivation
Figure 4

Odds ratios of hospitalised COVID-19 patients presenting with multilobar pneumonia, requiring ITU admission and mortality (age and sex adjusted) (a) Odds ratios of presentation with multilobar pneumonia by: gender, ethnicity (BAME, Pakistani, Bangladeshi, Indian, Caribbean, African, Mixed, Chinese, Other ethnic group vs. Caucasian), admission from sub-indices of highest deprivation (Wider BHS deprivation, Indoor LE deprivation, Outdoor LE deprivation, Adult Skills deprivation) vs. admission from all other deprivation sub-indices of the respective deprivation form, admission to ITU vs. not admitted to ITU and mortality (age and sex adjusted) vs. discharge. (b) Odds ratios of ITU admission by: gender, ethnicity (BAME, Pakistani, Bangladeshi, Indian, Caribbean, African, Mixed, Chinese, Other ethnic group vs. Caucasian), admission from sub-indices of highest deprivation (wider BHS deprivation, Indoor LE deprivation, Outdoor LE deprivation, Adult Skills deprivation) vs. admission from all other deprivation sub-indices of the respective deprivation form and presentation with pneumonia (radiological pneumonia vs. radiological multilobar pneumonia) vs. presentation without pneumonia; (c) Odds ratios of age and sex adjusted mortality by: gender, ethnicity (BAME, Pakistani, Bangladeshi, Indian, Caribbean, African, Mixed, Chinese, Other ethnic group vs. Caucasian), admission from sub-indices of highest deprivation (wider BHS deprivation, Indoor LE deprivation, Outdoor LE deprivation, Adult Skills deprivation) vs. admission from all other deprivation sub-indices of the respective deprivation form, presentation with pneumonia (radiological pneumonia, radiological multilobar pneumonia) vs. presentation without pneumonia and ITU admission vs. not admitted to ITU.
Figure 5

Odds ratios of mortality among COVID-19 patients by underlying obesity, hypertension, ischaemic heart disease, heart failure, peripheral vascular disease, COPD, type 2 diabetes mellitus, liver cirrhosis and chronic kidney disease.

Figure 6
Odds ratios of hospitalised COVID-19 positive patients of (a) Pakistani, (b) Indian, (c) Bangladeshi, (d) African, (e) Caribbean, (f) Chinese, (g) mixed and (h) any other ethnicity by: admission from sub-indices of highest deprivation (wider BHS deprivation, Indoor LE deprivation, Outdoor LE deprivation, Adult Skills deprivation), ITU admission and mortality (age and sex adjusted).

Supplementary Files

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- Onlinesupplementn.pdf