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TITLE

Oxygenation of the critically ill in selected English intensive care units: are we usual?

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For Peer Review

ABSTRACT

Recent data suggest a conservative approach to oxygen use in acutely unwell patients could be beneficial compared to more liberal use; guidance also suggests oxygen saturation (SpO₂) should not exceed 96-98% in those receiving oxygen. Using data from 12 English intensive care units (ICUs), we demonstrated that in 29,657 patient episodes the average SpO₂ was 96.2% and 97.2% for medical and surgical patients, respectively. Furthermore, 61% and 23% of patients receiving supplemental oxygen spent at least half their time in ICU with SpO₂ readings >96% and >98% respectively. Patients managed on English ICUs tend to have a higher SpO₂ than has been recommended for non-critically ill, acutely unwell patients.

For Peer Review

BACKGROUND

Maintaining adequate arterial oxygenation for cellular respiration is a cornerstone of the management of critically ill patients. The potential for excessive ('liberal') administration of supplemental oxygen to cause harm has recently been highlighted in a systematic review and meta-analysis,¹ but only three studies included mechanically ventilated patients on an intensive care unit (ICU). Subsequent guidance for oxygenation in the acutely unwell patient recommended avoiding an oxygen saturation (SpO₂) greater than 96%.² Similarly BTS guidance suggests limiting SpO₂ to between 94-98%.³ The recently published ICU-ROX trial from 21 Australasian intensive care units comparing 'conservative' and 'usual' oxygen use could not detect a difference between the two groups for the primary outcome measure, ventilator-free days.⁴ A crucial factor overlooked in many areas of clinical research is what constitutes usual or standard care. Comparison of an intervention to non-standard care, may produce results that lack relevance and effect the reported efficacy of the intervention. Without an understanding of what usual practice looks like, designing meaningful studies in this area will be challenging. We aimed to determine usual care for oxygenation in patients admitted to selected ICUs in England.

METHODS

This study interrogated data from the NIHR critical care health informatics collaborative (CC-HIC). The CC-HIC aggregates high fidelity time series data on patients from 12 university hospital ICUs in England.^{5,6} SpO₂ readings were extracted from January 2014 to July 2019. Inclusion criteria were all index admissions meeting minimum data quality standards. Raw data are presented as the proportion of time spent with SpO₂ >96% and >98%, and graphically as mean daily SpO₂. We used mixed effects regression to model SpO₂ as a function of *a priori* groups of interest: in receipt of supplemental oxygen (yes/no), surgical/medical status, mechanical ventilation status, any history of COPD (determined by the ICNARC coding method) and normalised age. SpO₂ values were nested within patients, with patients afforded random intercept and slope. A first order autocorrelation between serial SpO₂ values was assumed. Records with greater than 40% missingness for SpO₂ by hour were removed as they may represent cases with quality issues. Data were voluntarily censored at day 28 as cases beyond this time point are uncommon and no longer representative of the broader ICU population. All analyses were conducted in R.⁷

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3 A legal basis for transferring the data was provided under section 251 of the NHS Act 2006
4 (Confidentiality Advisory Group reference 14/CAG/1001). Ethics approval was granted by a
5 Health Research Authority Research Ethics Committee (14/LO/1031).
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8 9 **RESULTS**

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12 A total of 43,711 episodes (containing 6,860,423 individual SpO₂ recordings) met basic CC-
13 HIC quality control requirements. We identified 29,657 index patient episodes that met
14 inclusion criteria.
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19 Figure 1 shows the proportion of each ICU episode that patients spent with SpO₂ readings
20 greater than 96% or 98%, whilst receiving supplemental oxygen. 61% and 23% of patients
21 receiving supplemental oxygen, spent more than half of their ICU episode with SpO₂ readings
22 >96% or >98% respectively. 2,775 and 1,053 patients spent the entire duration of their ICU
23 episode receiving supplemental oxygen and with SpO₂ readings >96% or >98% respectively.
24 Results for overall patient daily mean SpO₂ are shown in Figure 2. Results from the mixed
25 effects model are shown in Table 1.
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32 All results are presented as coefficients with 95% CI. The model intercept is an SpO₂ of
33 96.18% [96.14%, 96.22%]. This is the predicted SpO₂ for unventilated, medical patients
34 without COPD, receiving supplemental oxygen at the population mean age (60.8 years). The
35 population random effect standard deviation was 2.2%, suggesting a large spread of data
36 around this value. Surgical patients had an SpO₂ 1.01% [0.95%, 1.07%] higher, while the
37 presence of COPD and cessation of supplemental oxygen lowered SpO₂ by 1.77% [1.89%,
38 1.65%] and 0.86% [0.88%, 0.84%], respectively. An increase in age by 17.5 years was
39 associated with a 0.36% [0.38%, 0.34%] lower SpO₂. This decrease, while statistically
40 significant, was not clinically significant. Time inside the ICU did not meaningfully influence
41 SpO₂.
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49 **DISCUSSION**

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52 Using high-fidelity data from largely unselected ICU patients we have demonstrated that
53 patients spend a high proportion of their ICU episode with potentially avoidable hyperoxaemia
54 (an SpO₂ >96% or >98% while receiving supplementary oxygen). Our findings show that,
55 independent of FiO₂ surgical patients have higher SpO₂ readings, potentially suggestive of
56 better baseline health. Just under two-fifths of UK ICU admissions are following surgery,⁸ a
57 high proportion of which will be elective. Though other factors such as a cultural use of oxygen
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3 during recovery from anaesthesia or concurrently with patient controlled analgesia should be
4 considered.
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8 An interesting observation from this study was the predicted SpO₂ for patients with COPD
9 receiving oxygen was 94.4%. This was surprising as current best practice guidance for
10 patients outside of the ICU setting with moderate to severe COPD is to target SpO₂ to 88-
11 92%.³ Only 25% of COPD patient-hours fell within this range, whilst receiving oxygen.
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15 This study could not address whether the SpO₂ values presented were within the targets set
16 by practitioners as this information is not collated by CC-HIC. Although the number of patients
17 included in this study was large, only 12 ICUs in teaching hospitals broadly restricted to the
18 South East of England were included in the analysis. Practice in these ICUs may not be
19 reflective of practice throughout the UK. This report is designed to be descriptive in nature,
20 though a major limitation will be the presence of informative censoring of data from death and
21 ICU discharge. Results will be biased toward patients who stay inside ICU alive for longer
22 periods in unpredictable ways.
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30 **CONCLUSION**

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33 In unselected patients from 12 English ICUs, SpO₂ was often higher than is currently
34 recommended in evidence-based guidelines for acutely unwell patients outside of the ICU.
35 This was independent of supplemental oxygenation or COPD status. With this in mind,
36 investigators designing studies must be mindful of local standards of care and whether study
37 results will be translatable to such a setting.
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DECLARATIONS

The views expressed are those of the authors and are not necessarily those of the NIHR, the NHS or the UK Department of Health and Social Care

COMPETING INTERESTS

DM: Consultancy for Siemens Healthineers and Edwards Lifesciences

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BP: Supported by the UKRI Centre for Doctoral Training in Artificial Intelligence for Healthcare

EP: Funded by MRC studentship.

AUTHORS CONTRIBUTIONS

BP: design of study, statistical analysis, and writing of manuscript.

EP: design of study, statistical analysis, and writing of manuscript.

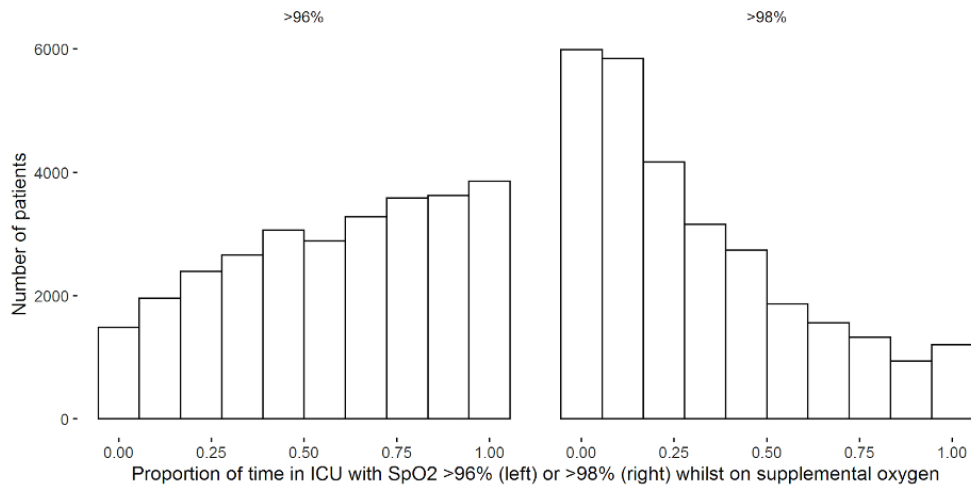
SH: revision of manuscript.

MS: revision of manuscript.

DM: design of study and writing of manuscript.

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Histogram displaying the proportion of ICU episode that each patient spent receiving supplementary oxygen with a peripheral oxygen saturation of greater than 96% or 98%.

159x79mm (150 x 150 DPI)