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

Benjamin Post[1,*,†], Edward Palmer[2,†], Steve Harris[2,3], Mervyn Singer[2,3] and Daniel Martin[4,5]

[1]Department of Bioengineering and Dept. of Computing, Imperial College London, London, UK, [2]Bloomsbury Institute of Intensive Care Medicine, University College London, UK, [3]Critical Care Unit, University College London, Hospitals NHS Foundation Trust, London, UK, [4]Division of Surgery and Interventional Science, Royal Free Hospital, London, UK and [5]Critical Care Unit, Royal Free Hospital, London, UK

*Corresponding author. E-mail: benjaminpost@doctors.org.uk

†Joint first authors.

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Editor—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 ICU. Subsequent guidance for oxygenation in the acutely unwell patient recommended avoiding an oxygen saturation (SpO_2) >96%.[2] Similarly, British Thoracic Society guidance suggests limiting SpO_2 to 94–98%.[3] The recently published ICU-ROX trial from 21 Australasian ICUs comparing 'conservative' and 'usual' oxygen use could not detect a difference between the two groups for the primary outcome measure of 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 can produce results that lack relevance and affect the reported efficacy of the intervention. Without understanding 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 the UK.

We interrogated data from the National Institute of Health Research (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 the UK.[5,6] SpO_2 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 SpO_2>96% and >98%, and graphically as mean daily SpO_2. We used mixed effects regression to model SpO_2 as a function of *a priori* groups of interest: receiving supplemental oxygen (yes/no), surgical/medical status, mechanical ventilation status, history of chronic obstructive pulmonary disease (COPD; determined by the Intensive Care National Audit & Research Centre (ICNARC) coding method) and normalised age. SpO_2 values were nested within patients, with patients afforded random intercept and

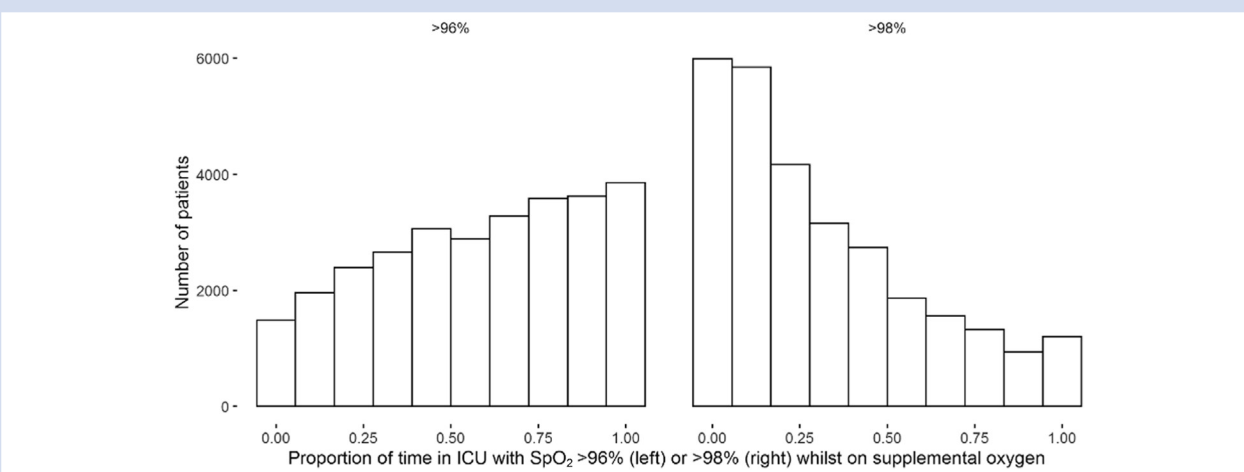

Fig 1. Histogram displaying the proportion of ICU episode that each patient spent receiving supplementary oxygen with a peripheral oxygen saturation of greater than 96% or 98%.

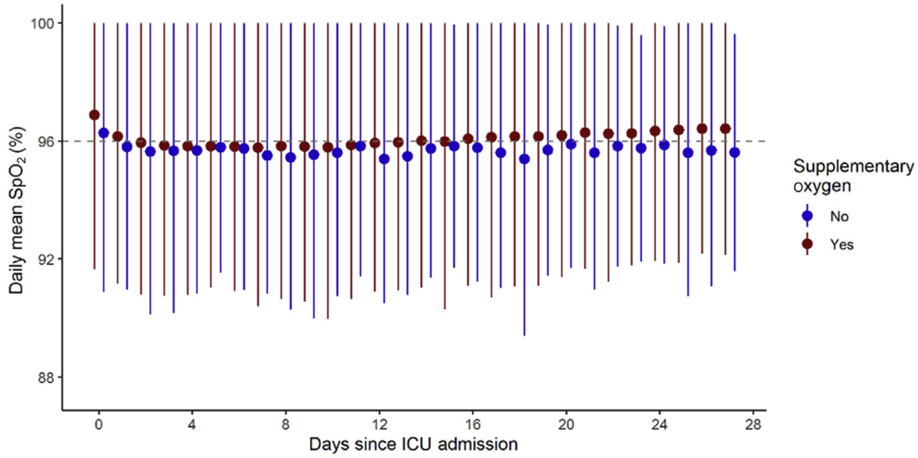

Fig 2. Daily mean SpO2 for patients inside ICU. Patients receiving or not receiving supplemental oxygen are shown in red and blue respectively.

slope. A first order autocorrelation between serial SpO_2 values was assumed. Records with greater than 40% missingness for SpO_2 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 Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. A legal basis for transferring data was provided under section 251 of the NHS Act 2006 (Confidentiality Advisory Group reference 14/CAG/1001). Ethics approval was granted by a Health Research Authority Research Ethics Committee (14/LO/1031).

A total of 43 711 episodes (containing 6 860 423 individual SpO_2 recordings) met basic CC-HIC quality control requirements. We identified 29 657 index patient episodes that met inclusion criteria. Figure 1 shows the proportion of each ICU episode that patients spent with SpO_2 readings >96% or >98%, whilst receiving supplemental oxygen: 61% and 23% of patients receiving supplemental oxygen spent >50% of their ICU episode with SpO_2 readings >96% or >98%, respectively. Some 2775 and 1053 patients spent the entire duration of their ICU episode receiving supplemental oxygen and with SpO_2 readings >96% or >98%, respectively. Results for overall patient daily mean SpO_2 are shown in Figure 2. Results from the mixed effects model are shown in Table 1.

All results are presented as coefficients with 95% confidence intervals. The model intercept is an SpO_2 of 96.2% (96.1% − 96.2%). This is the predicted SpO_2 for unventilated, medical patients without COPD, receiving supplemental oxygen at the population mean age (60.8 yr). The population random effect standard deviation was 2.2%, suggesting a large spread of data around this value. Surgical patients had an SpO_2 1.0% (0.95%, 1.07%) higher, while the presence of COPD and cessation of supplemental oxygen lowered SpO_2 by 1.77% (1.89%, 1.65%) and 0.86% (0.88%, 0.84%), respectively. An increase in age by 17.5 yr was associated with a 0.36% (0.38%, 0.34%) lower SpO_2. This decrease, while statistically significant, was not clinically significant. Time inside the ICU did not meaningfully influence SpO_2.

Using high-fidelity data from largely unselected ICU patients we observe that patients spend a high proportion of their ICU episode with potentially avoidable hyperoxaemia (SpO_2 >96% or >98% while receiving supplementary oxygen). Our findings show that, independent of FiO_2, surgical patients have higher SpO_2 readings, suggestive of better baseline health. Just under 40% of UK ICU admissions are after surgery,[7] a high proportion of which will be elective. However, other factors such as a cultural use of oxygen during recovery from anaesthesia or concurrently with patient-controlled analgesia should be considered.

The predicted SpO_2 for patients with COPD receiving oxygen was 94%. This was surprising as current best practice guidance for patients outside of the ICU setting with moderate to severe COPD is to target SpO_2 to 88–92%.[3] Only 25% of COPD patient-hours fell within this range whilst receiving oxygen.

Table 1. Results from the mixed effects model.

Factor	Value	Standard error	DF	t-value	P-value
Intercept	96.18	0.02	2967270	4760.51	$<1\times10^{16}$
Time	−0.01	0.00	2967270	−43.57	$<1\times10^{16}$
On room air	−0.86	0.01	2967270	−75.28	$<1\times10^{16}$
Surgical	1.01	0.03	29653	39.21	$<1\times10^{16}$
Ventilated	0.42	0.01	2967270	45.25	$<1\times10^{16}$
COPD	−1.77	0.06	29653	−30.50	$<1\times10^{16}$
Normalised age	−0.36	0.01	29653	−27.64	$<1\times10^{16}$

COPD, chronic obstructive pulmonary disease; DF, degrees of freedom

This study could not address whether SpO_2 values were within the targets set by practitioners as this information is not collated by CC-HIC. Although the number of patients included was large, only 12 ICUs in teaching hospitals broadly restricted to the South East of England were included in the analysis. Practice in these ICUs may not be reflective of practice throughout the UK. This report is descriptive in nature, although a major limitation will be the presence of informative censoring of data from death and ICU discharge. Results will be biased towards patients who stay inside ICUs alive for longer periods in unpredictable ways.

In unselected patients from 12 UK ICUs, SpO_2 was often higher than is currently recommended in evidence-based guidelines for acutely unwell patients outside of the ICU. This was independent of supplemental oxygenation or COPD status. With this in mind, investigators designing studies must be mindful of local standards of care and whether study results will be translatable to such a setting.

Authors' contributions

Design of study, statistical analysis, and writing of manuscript: BP, EP
Revision of manuscript: SH, MS
Design of study and writing of manuscript: DM

Declarations of interest

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. DM is a consultant for Siemens Healthineers and Edwards Lifesciences. The other authors declare that they have no conflicts of interest.

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