Clinical paper

$SpO_2$ values in acute medical admissions breathing air—Implications for the British Thoracic Society guideline for emergency oxygen use in adult patients?∗

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ABSTRACT

$SpO_2$ is routinely used to assess the well-being of patients, but it is difficult to find an evidence-based description of its normal range. The British Thoracic Society (BTS) has published guidance for oxygen administration and recommends a target $SpO_2$ of 94–98% for most adult patients. These recommendations rely on consensus opinion and small studies using arterial blood gas measurements of saturation ($SaO_2$). Using large datasets of routinely collected vital signs from four hospitals, we analysed the $SpO_2$ range of 37,593 acute general medical inpatients (males: 47%) observed to be breathing room air. Age at admission ranged from 16 to 105 years with a mean (SD) of 64 (21) years. 19,642 admissions (52%) were aged ≥18 years provided results that were distinctly different to those upon which the current BTS guidelines based their definition of normality. Our findings suggest that the BTS should consider changing its target saturation for actively treated patients not at risk of hypercapnic respiratory failure to 96–98%.

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1. Introduction

Oxygen saturation is a measure of the percentage of the circulating haemoglobin combined with oxygen. When measured by pulse oximetry, this is termed $SpO_2$. Despite being considered an important vital sign for assessing the well-being of patients, it is surprisingly difficult to find an evidence-based description of the normal range for $SpO_2$ in textbooks or research publications.

In October 2008, the British Thoracic Society (BTS) published a guideline for emergency oxygen use in adult patients. It suggests “...aiming to achieve normal or near-normal oxygen saturation for all acutely ill patients apart from those at risk of hypercapnic respiratory failure or those receiving terminal palliative care...” and recommends a target $SpO_2$ of 94–98% for most adults. The BTS efforts to produce an evidence-based and up-to-date guideline were hampered by the paucity of published data regarding $SpO_2$ values in normal humans. Consequently, the BTS definitions of “normal” and “near-normal” rely heavily on consensus opinion and small studies using arterial blood gas measurements of $PaO_2$ or $SaO_2$.∗∗

The BTS review did not include the results of a large American study of $SpO_2$ values in a group of 871 “healthy” patients, visitors and hospital employees breathing air, which was published in February 2008, and which reported that most asymptomatic adults had $SpO_2$ values between 98% and 100%. Over 98% of $SpO_2$ values in that study were ≥96%.8 Portsmouth Hospitals NHS Trust, University Hospitals Coventry and Warwickshire NHS Trust, Royal Shrewsbury Hospital and Princess Royal Hospital, Telford have established large, and growing, databases of vital signs data, including $SpO_2$, recorded electronically using the same electronic system.9 We analysed...
these datasets to determine the $SpO_2$ range seen in acute medical admissions in these hospitals and to compare our findings with previously recommended ranges.2–8

2. Methods

The study took place in the Medical Assessment Unit of Portsmouth Hospitals NHS Trust and the medical wards of the University Hospitals Coventry and Warwickshire NHS Trust, Royal Shrewsbury Hospital and Princess Royal Hospital, Telford. Research ethics committee approval was obtained prior to the commencement of this study.

All study hospitals used the same electronic vital signs charting system in which nurses routinely documented all vital signs (i.e., heart rate, breathing rate, blood pressure, temperature, $SpO_2$, conscious level) data at the time of measurement. This system used commercially available, personal digital assistants (PDA) running specifically designed software (VitalPAC®; The Learning Clinic).9 The PDAs were linked by wireless local area networks (W-LAN) to the hospital intranet, where vital signs data were stored and integrated with patient demographic information. $SpO_2$ values were recorded in the PDAs together with a simultaneous and linked record of the inspired gas (i.e., air or oxygen) being breathed by the patient at the time of $SpO_2$ measurement. The assessment of whether the patient was receiving oxygen or air was made in real time by direct observation of the patient by the nurse entering these data. These data were not obtained from oxygen prescription charts, the patient notes or other records.

For each patient in each hospital, $SpO_2$ was measured using whatever device was in clinical use. In Portsmouth, this was most often a Datascope Passport 2 multiparameter portable bedside monitor (Datascope Corporation, New Jersey, USA). Specified accuracy, ±2 units. All oximeters were automatically self-calibrating and were checked annually by the hospital Clinical Engineering department using a BioTek Index Pulse Oximeter tester. In the University Hospitals Coventry and Warwickshire NHS Trust, $SpO_2$ was measured using either a Masimo $SpO_2$ monitor or a GE Healthcare Dash monitor. All were checked annually for electrical safety and accuracy. Accuracy was checked using a Metron daeg $SpO_2$ analyzer calibrated by a recognised test house. At Shrewsbury and Telford Hospitals, $SpO_2$ was measured using one of the following monitors: Welch Allyn 300 series; Phillips SureSigns VM6; Criticare VitalCare 506N3 or Mindray MEC-1200. All oximeters were checked annually using a Prank TechnologiesOX-1 OxSim® Miniaturized Optical $SpO_2$ Pulse Oximeter Tester.

Where there were multiple episodes of care for the same patient in the study period, we made an a priori decision to exclude all but the first episode from the analysis. Within the episode, we only analysed the first recorded value of $SpO_2$. An a priori decision was made to exclude from further analysis all values of $SpO_2$ <70% on the basis that such values were likely to be inaccurate. Only patients observed to be receiving air at the time of $SpO_2$ measurement were included in the analysis. Data from non-acute admissions were also excluded from the final analysis. We also collected the final hospital outcome (alive/dead) for all individual patients. The final patient demographic and vital signs data were analysed using a Microsoft® Visual FoxPro 9.0 database and SPSS v16.

3. Results

In the database, there was a total of 62,554 unique patient episodes for 46,759 unique patients where $SpO_2$ values exceeded 69%. $SpO_2$ values of 97%, 96% and 95% were acute admissions (males 17,779; females 19,814).
was 3.65% (3.22–4.13); 4.47% (3.99–5.00); and 5.67% (5.03–6.38), respectively.

Table 2 shows summary statistics, broken down by age, for SpO2 for 37,299 medical admissions aged ≥18 years. This age breakdown is the same as Table 7 of the BTS guideline paper1 which only considers patients ≥18 years. Further breakdown of these data for 14,558 patients aged ≥75 years is provided in Table 3.

### 4. Discussion

This large study measured the SpO2 values of patients observed to be breathing air, in four UK hospitals. Some of these patients were acutely unwell. Summary descriptive statistics of SpO2 derived from this group can reasonably be expected to be less than those that would be obtained from the normal healthy population.

Despite this, the mean values of SpO2 for increasing age groups (Table 2) were consistently higher than the SpO2 values described by Crapo et al.2 for 96 healthy volunteers at sea level, which formed the basis for both the ‘normal’ range for oxygen saturation and the SpO2 target range of 94–98% recommended in the BTS guidelines.1 A direct comparison of the data that we present with those described in Crapo et al.’s paper demonstrates that our patient population was much older. 56% of our patients were ≥65 years compared to 23%; 20% of our patients were <45 years compared to 60% in the Crapo study.

Our results have much in common with the data presented by Witting and Scharf, who found that most of the asymptomatic adults in their study of 871 “healthy” awake subjects had SpO2 values between 98% and 100%.8 Their median (IQR) value was 99% (98–100%) compared to ours of 97% (95–98%). Only 8% of their cohort of patients was aged ≥60 years. The proportions of females in the two studies were almost identical (Witting 52%; current study 53%), but 66% of the subjects in Witting and Scharf’s study were African American, 577 (66%). Although Witting and Scharf found only minor effects of age, gender, race and smoking history on SpO2 values, they reported slightly lower SpO2 readings for Caucasians and males.8

We did not study race or smoking history, but found no clinically significant differences in SpO2 values on the basis of gender. There was only minimal widening of the SpO2 range with age (Table 2). Our results are not dissimilar from the unpublished audit of 320 stable hospital patients with no history of lung disease (referred to in the BTS guidelines1) which found a mean (SD) SpO2 of 96.7 (1.77)% in patients aged ≥71 years.

A major strength of our study is that the data were collected as part of the clinical and operational management of the patients. The patients were directly observed to be breathing air and this was recorded directly into our electronic vital signs system at the bedside. We consider it extremely unlikely that the nurses systematically recorded inaccurate data. Most importantly, the study had no reliance on oxygen prescription sheets, which have been shown to be inaccurate and inadequate for identifying patients receiving oxygen.10

Our study has some weaknesses. A variety of factors that we did not evaluate are known to influence SpO2 values.11–14 In patients with poor peripheral perfusion, e.g., shock, sepsis and hypotension, oximeters may underestimate the SpO2. It is likely that our study results include at least some such patients with these, but their inclusion would necessarily drive the mean SpO2 of the group down. Similarly, the inclusion of some patients with chronic lung disease would also inevitably lower the mean and median SpO2 values for the whole patient group. We did not record whether patients in our study were: smokers; suffering from acute carbon monoxide poisoning; hyperventilating; or in a sitting (as opposed to a supine) position at the time of SpO2 measurement. All these could elevate SpO2 values.

Our study population is not normal in that all subjects were acute medical admissions and, presumably, unwell. Therefore, it is likely that the measured SpO2 values were lower than if they had been recorded when the subjects were not acutely ill. This implies that our SpO2 distribution curves (Figs. 1 and 2) have probably been shifted to the left of those for an entirely normal population. On the other hand, it could be argued that we influenced the observed SpO2 distribution when, of necessity, we excluded 18.8% of patients from the analysis, because they were receiving oxygen. This might have influenced the observed SpO2 distribution by causing ‘normal’ low saturation values to be under-represented, since those with low SpO2 are the most likely to be given oxygen, whatever the guidelines. Several arguments exist to counter this assertion: (1) the existence of ‘low normal’ subjects is in itself a questionable concept, as the normal range for SpO2 has yet to be defined clearly; (2) none of the study hospitals had policies or guidelines for the indiscriminate use of oxygen to normalise SpO2 in otherwise healthy patients; (3) the SpO2 distribution patterns for all four study centres (Fig. 1) are virtually identical, implying that clinical practice in each centre would also have had to have been identical with respect to low normal subjects; (4) Witting and Scarf6 found that SpO2 values <96% and <97% are very rare (less than 1.5% and 5.7%, respectively); and (5) our results are also very similar to those of Witting and Scarf6 and the unpublished audit of stable hospital patients (referred to in the BTS guidelines1).
The BTS guideline for emergency oxygen use in adult patients is, in general, a comprehensive review of the theory and practice of acute oxygen treatment. Its strength has been its reliance on peer-reviewed research, thereby ensuring that the guidelines are up-to-date and evidence-based. However, it relies heavily on consensus opinion and small (maximum n = 194) studies using PaO2 or S\textsubscript{O2} to determine the target S\textsubscript{O2} range that underpins almost all of the recommendations. The guideline recommends that oxygen saturation should be checked by pulse oximetry in all breathless and acutely ill patients, and guides staff to target a normal or near-normal oxygen saturation (S\textsubscript{O2} 94–98%). Evidence has now emerged from two large studies – ours and that of Witting and Scarf\textsuperscript{8} – that the lower end of the BTS “normal” range for S\textsubscript{O2} may require re-consideration. Witting’s results suggest that only 5.7% of “normal” subjects will have S\textsubscript{O2} values below 97%\textsuperscript{8} and we found that 70.8% of the patients in our study, many of whom were acutely ill, had S\textsubscript{O2} values >96%.

Our data provide a large evidence base for the normal range of S\textsubscript{O2}. Data from two other independent studies (Wittings\textsuperscript{8}; unpublished audit described in BTS guidelines\textsuperscript{1}) support our findings. Consequently, we believe that consideration should be given to raising the lower end of the suggested ‘normal’ S\textsubscript{O2} range from the BTS’ value of 94% to a new value of 96% for actively treated patients not at risk of hypercapnic respiratory failure. The additional finding in our study that the 95% CI for mortality for patients with initial S\textsubscript{O2} values of 96% (3.99–5.00) do not overlap with those for patients with initial S\textsubscript{O2} values of 95% (5.03–6.38) provides some support to the choice of a new lower S\textsubscript{O2} limit of 96%, though, clearly, there are limitations to the use of final hospital outcome.

In practice, it is likely that clinicians will ignore the higher end of any suggested S\textsubscript{O2} range, as, once the lower end is reached, the target has effectively been achieved. However, we suggest that the BTS upper target of 98% for S\textsubscript{O2} is retained until such time that the existing controversies surrounding hyperoxia and its potential effects\textsuperscript{12–19} are settled convincingly. Therefore, we suggest that consideration is given to adopting a new target range of 96–98%. Our data does not show a need for adopting a different target S\textsubscript{O2} for different ages or gender.

**Conflict of interest statement**

VitalPAC is a collaborative development of The Learning Clinic Ltd (TLC) and Portsmouth Hospitals NHS Trust (PHT). PHT has a royalty agreement with TLC to pay for the use of PHT intellectual property within the VitalPAC product. Professor Prytherch and Drs Schmidt, Featherstone and Meredith are employed by PHT. Professor Smith was an employee of PHT until 31/03/2011. Dr Schmidt, and the wives of Professors Smith and Prytherch are shareholders in TLC. Professors Smith and Prytherch, and Dr Schmidt, are unpaid research advisors to TLC. Professors Smith and Prytherch have received reimbursement of travel expenses from TLC for attending symposia in the UK.

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**References**


