The Effect of Body Position on Arterial Oxygen Saturation in Acute Stroke

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Background. Evidence suggests that respiratory function is impaired poststroke. Body position is known to influence respiratory function in normal subjects and those with respiratory pathologies. Its effect on respiratory function after stroke has received little attention. However, one study suggests that some positions used in clinical practice may adversely influence respiratory function. This study therefore aimed to identify resting positions that maintain arterial oxygen saturation (SaO2) at optimal levels, changes in SaO2 during time spent in the test position, and differences in SaO2 among the positions investigated.

Method. A within-subject, two-center clinical study was made. Patients in the first 72 hours following mild to moderately severe stroke were allocated a randomized sequence of four positions. One hour was spent in each position. SaO2 was recorded each minute by pulse oximetry with a finger probe. Mean values for the hour were calculated.

Results. Mean arterial oxygen saturation values for all patients were >90% for the hour spent in each test position for all patients. There were no changes in arterial oxygen saturation across the hour spent in the test positions (repeated-measures analysis of variance). No differences in arterial oxygen saturation were identified among positions (analysis of covariance).

Discussion. The saturation levels recorded corresponded to those observed in studies of normal elderly persons. The positions tested may be recommended for use in clinical practice to maintain arterial oxygen saturation in patients in the first 72 hours following mild to moderately severe stroke.

During the acute phase after stroke one of the main aims of treatment is to minimize cerebral damage (1). Following an ischemic event there is an infarcted region surrounded by a penumbra of potentially recoverable but compromised tissue (2). Acute delivery of oxygen to this tissue is of paramount importance as anaerobic glycolysis is associated with the production of lactate and cell death (1). Arterial oxygen desaturation has been associated with increased mortality and morbidity poststroke (3). This might have implications for potentially recoverable tissue, although direct experimental evidence of an effect on penumbral tissue is not available for ethical reasons. However, even if modest levels of hypoxia do not threaten the ischemic penumbra, it might be anticipated that hypoxia may have adverse effects on cerebral function and hence on rehabilitation. One way of improving oxygen delivery may be through positioning patients to optimize the ventilation–perfusion ratio.

Positioning to optimize the ventilation–perfusion ratio is accepted practice in the management of respiratory conditions with differences in arterial oxygen levels being identified between positions (4,5). There is direct evidence from transcranial magnetic stimulation that cortical drive of diaphragmatic activity can be impaired poststroke (6). There is also direct evidence of reduced ventilation in such patients (7). In stroke care physiotherapists recommend specific positions to modulate muscle tone (8–10), but little direct evidence exists to support this. Moreover, some of the positions used, for example side lying, have been associated with arterial oxygen desaturation in patients with severe motor impairment in the acute phase of stroke (11).

A range of positions, in which arterial oxygen saturation is maintained at optimal levels for the whole time the patient spends in the position, is required to suit the varying needs of the acute stroke population and to achieve other aspects of good management, such as pressure area care. Blood pressure must also be maintained in these positions as postural hypotension may result in decreased cerebral perfusion, contributing to further ischemic damage (12,13).

We therefore examined the influence on oxygen saturation of placing stroke patients in positions that, based on ventilation–perfusion studies, would be expected to optimize arterial oxygen saturation. We hypothesized that (a) there was a difference in arterial oxygen saturation between the four test positions, (b) alterations in arterial oxygen saturation would be observed in the course of a 1-hour test period, and (c) there would be a correlation between arterial oxygen saturation and severity of stroke. A subsidiary hypothesis also tested was that there was a correlation between respiratory rate and arterial oxygen saturation.

Method
A within-subject, two-center, clinical study was undertaken following a pilot study that utilized the same protocol. A re-
search physiotherapist identified patients who had a clinical diagnosis of stroke within the first 72 hours of onset.

Patients were excluded if they had hypothermia, pyrexia, anemia, acute respiratory infection, if they were cardiovascularly unstable, if they had a condition that could result in a preexisting restrictive respiratory deficit, if they were medically unwell, if they were receiving medication that would depress respiratory function, or if they were not for active treatment, such as physiotherapy or antibiotics.

Approval was obtained from the Local Ethical Committees. Informed consent or relatives’ assent was obtained. Stroke severity was then assessed with the European Stroke Scale (14) and the trunk section of the Motricity Index (15).

Saturation was recorded every minute for 1 hour in each of the four test positions with a Nellcor Symphony 3000 pulse oximeter and DS-100A Durasensor finger probe. The number of episodes of desaturation was recorded. An episode of desaturation was defined as arterial oxygen saturation <90% for 3 or more minutes. Respiratory rate was recorded after 5 and 55 minutes in a test position. The number of breaths observed over a 30-second period was counted and multiplied by 2.

Position sequence was determined by a modified randomization procedure to avoid ordering effects and to ensure that the data collected corresponded to the first 60 minutes spent in the test position. If the patient was already in the test position, or one closely approximating it, this position was excluded from the randomization process at that stage. The position was then included in the process when the next position was selected.

The positions selected for testing were
• Lying in bed on the hemiplegic side, with the backrest at a 45° incline
• Lying in bed on the nonhemiplegic side, with the backrest at a 45° incline
• Sitting up in bed with the backrest at 70° incline
• Sitting in an armchair

A detailed description can be found in the Appendix. Limb alignment corresponded to the positions identified as being those most frequently recommended in stroke rehabilitation literature (10).

An analysis of pilot study data suggested that a minimum of 12 patients would be needed to complete each position to have an 88% power to detect a difference of 2% (standard deviation of difference = 2%) in oxygen saturation.

For each test position, the 1-hour study period was divided into four 15-minute intervals; mean arterial oxygen saturation was then computed for each of these intervals and for the whole hour. Changes in arterial oxygen saturation and respiratory rate within each study period were analyzed separately with paired t tests. Differences between the four test positions were evaluated with repeated-measures analysis of (co)variance, with baseline values used as covariates where appropriate. European Stroke Scale and trunk Motricity Index were considered to follow nonnormal distributions, so the strengths of the relationships between these and arterial oxygen saturation were estimated with the Spearman correlation coefficient. Statistical significance was set at the conventional 5% level. All computations were done with the SPSS for Windows statistical computer package.

**Results**

From the 287 patients screened, 24 patients were admitted to the study. The number of patients completing each position ranged from 12 to 17. Patient characteristics are shown in Table 1.

The following were reasons for nonadmission: 96 patients were either not identified or were unable to be tested within the time constraints of the study, we were unable to gain consent or relatives’ assent from 45 patients. 42 patients did not have a formal medical diagnosis of stroke, 37 patients had previous neuropathology, 24 patients had concurrent or preexisting pathology that would interfere with respiratory measures, 20 patients were medically unsuitable to participate in study, 9 patients were discharged early or transferred to another unit, 16 patients were out of the age range for the study, 6 patients died, and it was considered ethically inappropriate to approach 5 patients because of their external circumstances.

Not every patient was able to complete all positions. Reasons identified for not completing all four positions were inability to adopt sitting postures, some patients declined to complete all positions, inability to complete all positions within time constraints of study, and one patient was withdrawn because of extension of stroke.

Fifty-six hours of data were analyzed. No episodes of desaturation were recorded. There was no significant difference in mean arterial oxygen saturation for the full hour between the positions tested (Table 2).

As arterial oxygen saturation may change over the time spent in a position, it was important to analyze the data to detect such trends. No significant differences were found across the 1-hour period when the means of the 15-minute intervals were compared (Table 3).

The relationships among the mean saturation over the hour and measures of stroke severity and level of consciousness were investigated. There was no significant correlation between the Motricity Index and arterial oxygen saturation

<table>
<thead>
<tr>
<th>Table 1. Sample Patient Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Mean (SD)</td>
</tr>
<tr>
<td>Gender Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Diagnosis Left-hemisphere CVA Infarct</td>
</tr>
<tr>
<td>Hemorrhage</td>
</tr>
<tr>
<td>Right-hemisphere CVA Infarct</td>
</tr>
<tr>
<td>Hemorrhage</td>
</tr>
<tr>
<td>Brainstem CVA Infarct</td>
</tr>
<tr>
<td>Cerebellar CVA Hemorrhage</td>
</tr>
<tr>
<td>Stroke severity European Stroke Scale (range 0–100) Median</td>
</tr>
<tr>
<td>Interquartile range</td>
</tr>
<tr>
<td>Motricity Index (Trunk section, range 0–100) Median</td>
</tr>
<tr>
<td>Interquartile range</td>
</tr>
<tr>
<td>Respiratory pattern Normal</td>
</tr>
<tr>
<td>Cheyne–Stokes variants</td>
</tr>
<tr>
<td>Cheyne–Stokes respiration</td>
</tr>
<tr>
<td>Smoking history Current smoker</td>
</tr>
<tr>
<td>Exsmoker</td>
</tr>
<tr>
<td>Never smoked</td>
</tr>
</tbody>
</table>

Notes: SD = standard deviation, CVA = cerebrovascular accident.
Table 2. Mean Arterial Oxygen Saturation for the Hour Spent in the Test Positions

<table>
<thead>
<tr>
<th>Positions*</th>
<th>N</th>
<th>Mean, %</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting in chair</td>
<td>12</td>
<td>96.39</td>
<td>1.42</td>
<td>92.67</td>
<td>98.80</td>
</tr>
<tr>
<td>Right-side lying at 45°</td>
<td>17</td>
<td>96.33</td>
<td>1.74</td>
<td>93.08</td>
<td>99.65</td>
</tr>
<tr>
<td>Left-side lying at 45°</td>
<td>14</td>
<td>96.54</td>
<td>1.69</td>
<td>94.18</td>
<td>99.03</td>
</tr>
<tr>
<td>Sitting in bed at 70°</td>
<td>13</td>
<td>95.76</td>
<td>2.19</td>
<td>91.52</td>
<td>98.52</td>
</tr>
</tbody>
</table>

*Test statistics for differences between positions (analysis of covariance) \( F(3,29) = 1.14, p = .350 \).

(r = 0.006, p = .483), between European Stroke Scale and arterial oxygen saturation \( r = -0.184, p = .088 \), or the level of consciousness section of the European Stroke Scale and arterial oxygen saturation \( r = -0.098, p = .236 \).

No significant changes in respiratory rate were found among the different positions (Table 4). However, a significant difference was found in respiratory rate across the hour spent sitting in bed. The difference was 1.6 breaths, which could be explained by measurement or procedural error. This size of difference is not clinically significant.

**Discussion**

Saturation values were maintained at acceptable values, and there did not appear to be a significant difference in arterial oxygen saturation between the positions tested. Data show little variability among positions and across the hour. Average values for oxygen saturation were higher than those expected in the study by Elizabeth and colleagues (11), which may imply the possibility of a ceiling effect, in other words, maximal saturation value may be achieved while PaO\(_2\) is still able to increase. Moreover, it does suggest that patients in the current study were more similar to the normal population (16) than patients in the study by Elizabeth and colleagues. It is noteworthy that the values observed were higher than those we anticipated on the basis of the latter study but their patients were older and had greater motor impairment. However, the values in the current study are similar to those recorded by other investigators (17), who found the differences to be significant. Such small differences in arterial oxygen saturation (0.4%) lack clinical significance, and statistical significance may be explained by the size of the study (17).

It has been suggested that arterial oxygen saturation levels are significantly greater in more upright positions (11,17). The positions investigated in the current study were ones in which head and shoulders were elevated. The results of systematic investigations, of normal subjects and those with respiratory pathologies, support the selection of more upright positions in terms of ventilatory mechanics and ventilation–perfusion matching (5,18). This may be one reason why arterial oxygen saturation was higher in the current study than in a study in which more recumbent positions were used (11).

An alternative explanation may be the sensitivity of the measure used. Pulse oximetry is relatively insensitive at the upper end of the oxygen dissociation curve. A large drop in arterial oxygen tension has to occur before arterial oxygen saturation falls (19). Conversely, small changes in arterial oxygen saturation signify larger changes in oxygen tension. This may explain why no differences were seen among positions. Oxygen tension may have been a more sensitive measure but would have been less suitable for identifying changes across the hour and immediate identification of hypoxic events. However, although very small changes in PaO\(_2\) may be missed at the high end of the dissociation curve, these are unlikely to be relevant to the issue of cerebral ischemia.

Differences in time since onset of stroke may explain the differences in arterial oxygen saturation values recorded between our study and previous studies. In the current study testing took place between 24 and 72 hours poststroke. Ideally monitoring of arterial oxygen saturation would occur immediately poststroke as the therapeutic window for intervention to rescue critically ischemic tissue is of limited duration (1). Unfortunately, the informed consent procedure in this vulnerable group of patients made this unrealistic.

Severity of stroke may explain the difference in arterial oxygen saturation values recorded between earlier studies and ours. However, direct comparisons are difficult to make because of the different stroke severity scales used. The current study investigated the relationship between measures of stroke severity and saturation. No significant correlations were found. This may have been influenced by the high proportion of less severe strokes admitted to the current study, as evident in the European Stroke Scale and Motricity Index data. It is possible that oxygen transfer is compromised only in patients with very severe stroke in whom there may be the additional problem of central neurogenic hyperventilation.

Ventilatory dynamics and arterial oxygen levels are

Table 3. Changes in Arterial Oxygen Saturation Across the Hour Spent in the Test Positions

<table>
<thead>
<tr>
<th>Positions*</th>
<th>Mean of First 15-Minute Interval (SE)</th>
<th>Mean of Second 15-Minute Interval (SE)</th>
<th>Mean of Third 15-Minute Interval (SE)</th>
<th>Mean of Fourth 15-Minute Interval (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting in chair</td>
<td>96.40 (0.441)</td>
<td>96.36 (0.453)</td>
<td>96.43 (0.396)</td>
<td>96.37 (0.372)</td>
</tr>
<tr>
<td>Right-side lying at 45°</td>
<td>96.29 (0.391)</td>
<td>96.24 (0.440)</td>
<td>96.30 (0.473)</td>
<td>96.50 (0.417)</td>
</tr>
<tr>
<td>Left-side lying at 45°</td>
<td>96.88 (0.448)</td>
<td>96.37 (0.472)</td>
<td>96.43 (0.479)</td>
<td>96.46 (0.481)</td>
</tr>
<tr>
<td>Sitting in bed at 70°</td>
<td>95.96 (0.563)</td>
<td>95.70 (0.648)</td>
<td>95.67 (0.633)</td>
<td>95.72 (0.616)</td>
</tr>
</tbody>
</table>

Note: SE = standard error.

*Test statistics for differences across positions (repeated-measures analysis of variance):
Sitting in chair: \( F(3,33) = 0.122, p = .947 \).
Right-side lying at 45°: \( F(3,48) = 1.273, p = .294 \).
Left-side lying at 45°: \( F(3,39) = 2.578, p = .067 \).
Sitting in bed at 70°: \( F(3,36) = 1.210, p = .32 \).
known to decline with age (16). Differences in saturation levels between previous studies and ours may be due to differences in sample age. The mean age of patients in the current study was 12 years fewer than those investigated by Elizabeth and colleagues (11). However, post hoc analysis of our results did not demonstrate a significant correlation between age and arterial oxygen saturation. Problems were encountered in patient recruitment. By the time patients were identified and screened, gaining consent within 72 hours presented difficulties, particularly as patients were encouraged to discuss participation with relatives. Contacting relatives to gain assent when patients were unable to consent was even more problematic. This may have resulted in an unrepresentative sample, with a bias to less severe cases. It also resulted in some patients not being able to undertake all four test positions.

Patients in the current study were observed to have moderately high respiratory rates. Similar rates in stroke patients have been identified by other investigators in comparison with age-matched controls (20). These respiratory rates may explain the higher-than-expected oxygen saturation recorded. However, analysis did not demonstrate a significant correlation between respiratory rate and oxygen saturation in the current study.

Conclusion

The positions tested appear to maintain arterial oxygen saturation at satisfactory levels. No significant differences in oxygen saturation were identified between the positions. These positions may be recommended for clinical use in order to achieve optimal oxygen saturation in this milder group of stroke patients.

Acknowledgments

The authors thank The Stroke Association and The North West R&D Directorate for their financial assistance, the clinical staff who assisted with identifying and positioning patients, the patients for participating in the study, and Dr. P. Tyrell and Dr. D. Evans for their advice and support.

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References


Table 4. Changes in Respiratory Rate Across the Hour Spent in Test Positions

<table>
<thead>
<tr>
<th>Position*</th>
<th>5 minutes</th>
<th>55 minutes</th>
<th>Mean Increase (95% confidence interval)</th>
<th>Paired t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting in armchair</td>
<td>19.8 (3.4)</td>
<td>19.8 (4.2)</td>
<td>0 (–1.9 to 1.9)</td>
<td>t(10) = 0, p = 1.000</td>
</tr>
<tr>
<td>Right-side lying at 45°</td>
<td>20.2 (4.0)</td>
<td>20.9 (4.7)</td>
<td>0.7 (–0.3 to 1.8)</td>
<td>t(14) = 1.46, p = .166</td>
</tr>
<tr>
<td>Left-side lying at 45°</td>
<td>19.4 (3.6)</td>
<td>19.1 (3.7)</td>
<td>–0.3 (–1.8 to 1.2)</td>
<td>t(12) = 0.46, p = .656</td>
</tr>
<tr>
<td>Sitting in bed at 70°</td>
<td>19.8 (3.3)</td>
<td>21.4 (3.5)</td>
<td>1.5 (0.9 to 2.2)</td>
<td>t(12) = 4.92, p &lt; .001</td>
</tr>
</tbody>
</table>

Note: SD = standard deviation.
*Test statistics for differences between positions (repeated-measures analysis of variance):
5 minutes: F(3,29) = 0.44, p = .726.
55 minutes (covariate adjusted for 5-minute levels): F(3,25) = 2.46, p = .086.
### Appendix: Experimental Position

#### Sitting in chair
- **Head and neck**: Midline position
- **Trunk**: Supported, symmetrical, upright
- **Pelvis**: Slight anterior tilt, equal weight through both hips
- **Lower limbs**
  - **Hips**: 90° to trunk, support along thigh
  - **Knees**: 90°
  - **Feet**: Plantar grade, fully supported, slightly apart
- **Affected upper limb**
  - **Scapula**: Protracted
  - **Shoulder**: Flexed, slight abduction, and external rotation
  - **Elbow**: Flexed
  - **Forearm**: Pronated
  - **Wrist**: Neutral
  - **Fingers**: Extended
  - **Thumb**: Abducted
  - Weight of arm supported on a pillow

#### Sitting in bed, backrest at 70°
- **Head and neck**: Midline position
- **Trunk**: Symmetrical and upright, supported by pillows
- **Pelvis**: Equal weight through both hips
- **Lower limbs**
  - **Hips**: Hips 110° to trunk, legs straight out in front
  - **Knees**: Extended
  - **Feet**: Neutral
- **Affected upper limb**
  - **Scapula**: Protracted, slight abduction, and external rotation
  - **Shoulder**: Flexed
  - **Elbow**: Flexed
  - **Forearm**: Pronated
  - **Wrist**: Neutral
  - **Fingers**: Extended
  - **Thumb**: Abducted
  - Weight of arm supported on a pillow

#### Side lying on affected side, backrest at 45°
- **Head and neck**: Neutral
- **Trunk**: Supported, slight extension, some rotation to allow for arm positioning, should not be side flexed
- **Pelvis**: Greater trochanter should be up against base of backrest
- **Affected lower limb**
  - **Hips**: Flexed
  - **Knees**: Flexed
  - **Feet**: Midline, plantar grade
- **Unaffected lower limb**
  - **Hips**: Flexed
  - **Knees**: Flexed
  - **Feet**: Midline, plantar grade
  - Leg and foot supported on pillows, behind affected limb
- **Affected upper limb**
  - **Scapula**: Protracted
  - **Shoulder**: Flexed
  - **Elbow**: Extended
  - **Forearm**: Supinated
  - **Wrist**: Neutral
  - **Fingers**: Extended
  - **Thumb**: Abducted
  - Weight of arm supported on a pillow
- **Unaffected upper limb**
  - On or behind body, hand supported on pillow

#### Side lying on unaffected side, backrest at 45° angle
- **Head and neck**: Neutral
- **Trunk**: Supported, slight extension, some rotation to allow for arm positioning, should not be side flexed
- **Pelvis**: Greater trochanter should be up against base of backrest
- **Affected lower limb**
  - **Hips**: Flexed
  - **Knees**: Flexed
  - **Feet**: Midline, plantar grade
  - Leg and foot supported on pillows, in front of unaffected leg
- **Unaffected upper limb**
  - **Scapula**: Protracted
  - **Shoulder**: Flexed
  - **Elbow**: Extended
  - **Forearm**: Supinated
  - **Wrist**: Neutral
  - **Fingers**: Extended
  - **Thumb**: Abducted
  - Weight of arm supported on a pillow

(continued)
Appendix: Experimental Position (continued)

<table>
<thead>
<tr>
<th>Unaffected lower limb</th>
<th>Affected upper limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hips</td>
<td>Flexed</td>
</tr>
<tr>
<td>Knees</td>
<td>Flexed</td>
</tr>
<tr>
<td>Feet</td>
<td>Midline, plantargrade</td>
</tr>
<tr>
<td>Scapula</td>
<td>Neutral</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Slightly flexed</td>
</tr>
<tr>
<td>Elbow</td>
<td>Extended</td>
</tr>
<tr>
<td>Forearm</td>
<td>Supinated</td>
</tr>
<tr>
<td>Wrist</td>
<td>Neutral</td>
</tr>
<tr>
<td>Fingers</td>
<td>Extended</td>
</tr>
<tr>
<td>Thumb</td>
<td>Abducted</td>
</tr>
</tbody>
</table>

Weight of arm supported on a pillow

<table>
<thead>
<tr>
<th>Unaffected upper limb</th>
<th>Affected upper limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scapula</td>
<td>Protraced</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Flexed</td>
</tr>
<tr>
<td>Forearm</td>
<td>Pronated</td>
</tr>
<tr>
<td>Wrist</td>
<td>Neutral</td>
</tr>
<tr>
<td>Fingers</td>
<td>Extended, hand supported on folded towel</td>
</tr>
</tbody>
</table>