Day–night Differences in Oxygen Saturation and the Frequency of Desaturations in the First 24 Hours in Patients With Acute Stroke

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Background: Hypoxia is common after acute stroke. Most studies of oxygenation after stroke were done at night. The objective of this study was to determine whether there are differences in oxygenation between day and night early after stroke. *Methods:* Patients with an acute stroke were recruited within 24 hours of admission. Patients who were hypoxic (oxygen saturation < 90%) were excluded. Oxygen saturation was assessed by pulse oximetry over 24 hours. Daytime recordings were taken from 9 AM to 9 PM and nighttime recordings from 10 PM to 6 AM. Respiratory rate and sleep/awake status were recorded twice during the day and the night. *Results:* Forty patients were recruited (mean age 77 years [range 55-93 years], 53% men; median [range] Glasgow Coma Scale score 15 [10-15] and Scandinavian Stroke Scale score 31 [4-56]; 80% cerebral infarcts, 20% hemorrhages). The median (range) respiratory rate was 20 (14-30) breaths/min in the day and 18 (12-32) breaths/min in the night ($P < .01$, Wilcoxon paired test). The median (range) oxygen saturation was 95.5% (87%-98.6%) in the day and 94.3% (80%-98%) at night ($P < .001$, Wilcoxon paired test). The median (range) 4% oxygen desaturation index was 1.7 (0.0, 18.0) in the day and 3.0 (0.0, 39.4) at night ($P < .001$, Wilcoxon paired test). Respiratory rate, oxygen saturation, and 4% oxygen desaturation index during the day and night were strongly correlated. *Conclusions:* All indicators of oxygenation assessed in this study were significantly worse at night than in the day. Because daytime and nighttime results were strongly correlated, borderline hypoxia during the day is strongly predictive of overt hypoxia at night. **Key Words:** Stroke—hypoxia—oxygen—oxygen saturation—diurnal variation—sleep—apnea—day—night.

Hypoxia is a well-recognized clinical problem after stroke, and may be a result of changes in the central regulation of respiration,[1] effects of the stroke on respiratory muscles,[2,3] or complications of the stroke such as aspiration, pneumonia, pulmonary embolism,[4,5] and sleep apnea.[6,7] Guidelines for stroke management recommend monitoring of oxygen saturation as part of routine poststroke care.[8,9] Much of the recent research relating to poststroke breathing disorders has concentrated on sleep apnea[10-15] and was based on clinical studies using nocturnal polysomnography. Because the presumption is that sleep apnea is a problem that occurs at night when the patient sleeps, and because polysomnography involves multichannel monitoring, which would interfere with daytime activities and rehabilitation, data are only collected at night. In addition, most polysomnographic studies concentrate on respiration, but either do not re-

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port or only give limited information on oxygen saturation.

More recently a number of studies have addressed oxygenation early after stroke. Sulter et al[16] monitored 49 patients within 12 hours of hospital admission with stroke by pulse oximetry, and found that 63% of patients with stroke had an oxygen saturation of less than 96% for at least 5 minutes during the first 48 hours. Based on the results of a study by Ogburn-Russell and Johnson[17] addressing oxygen saturation at daytime, they postulate that normal oxygen saturation in older people is above 95% and, therefore, define hypoxia as saturation below 96%. In a study of 20 patients with stroke, Hui et al[18] report that the lowest nocturnal oxygen saturation was very low at 80.4% within 4 days of admission and slightly higher at 83.3% at 4 weeks later. In a study of nocturnal oxygen saturation in 100 patients with acute stroke and 85 matched control subjects, Roffe et al[19] have shown that oxygen saturation is 94.5% while the patient is awake at the beginning of the recording, and 1% lower while the patient is asleep (11 PM-6 AM). In the control group oxygen saturation while awake and during sleep was about 1% higher than in patients with stroke.

Although some studies have provided data on day–night differences in oxygen saturation,[19,20] there are no data on day–night differences in the prevalence of apneas. One reason for this is that apneas have mostly been linked with sleep (e.g., sleep apnea, sleep-disordered breathing); another reason is that assessment of apneas is most reliably performed via polysomnography, which is cumbersome and difficult to do in the day when the patient is awake, and possibly moving about.

Pulse oximetry provides reliable data on episodes of oxygen desaturation (the oxygen desaturation index [ODI]), which are strongly correlated with apneas (but may underestimate the prevalence of apneas because only apneas severe enough to cause hypoxia are recorded). Pulse oximetry is well tolerated, and can be used during a full 24-hour period without inconveniencing patients.

Apneic episodes resulting in oxygen desaturation may also occur during the day in patients with stroke. The objective identification of apnea in acute strokes, and its differentiation into central, obstructive, and mixed types necessitates sleep-related studies that may not be technically possible or convenient in acute strokes. Therefore, most studies tend to assess the outcome of apneic episodes in terms of oxygen desaturation. Most patients are assessed by clinicians while awake, and during the day. However, most of the data on respiration and oxygenation after stroke are based on studies conducted at night. So far, there are no detailed studies comparing daytime and nighttime oxygenation in patients with acute stroke.

The objectives of this study were to determine whether there are changes in oxygen saturation and the number of oxygen desaturations in patients with stroke between daytime and nighttime.

Methods

Trial Design and Participants

This was an observational study of changes in oxygen saturation throughout a 24-hour period in patients with acute stroke. Adult patients with a clinical diagnosis of acute stroke[21] were recruited within 24 hours of admission to the University Hospital of North Staffordshire, United Kingdom. Written informed consent was sought from all competent study participants. For the patients with stroke who were unable to give fully informed consent, assent from the next of kin was accepted. Patients with a definite indication for oxygen supplementation (oxygen saturation $< 90\%$, decompensated congestive cardiac failure, pneumonia with consolidation on the chest radiograph, known chronic hypoxia requiring long-term oxygen treatment) were excluded. Other reasons for study exclusion were: confusion and restlessness making probe placement difficult, reduced peripheral perfusion leading to unobtainable or poor oximetry trace, pregnancy, and refusal of consent. All patients were treated on an acute stroke department, where blood pressure, heart rate, temperature, and oxygen saturation was checked at least 4 times a day. The North Staffordshire Local Research Ethics Committee approved the study protocol.

Clinical Assessments

All patients with stroke were classified by clinical criteria into total anterior circulation syndrome, partial anterior circulation syndrome, lacunar syndrome, and posterior circulation syndrome using the Oxfordshire Community Stroke Project Classification.[22] Origin was determined by computed tomography (CT) of the head and grouped into cerebral infarcts and intracerebral hemorrhages (ICH). Hemorrhagic infarcts, and patients with clinical signs of stroke but nonspecific CT scan findings, were recorded as infarcts. Respiratory rate was assessed at rest by clinical observation twice in the day and night periods, and the mean of these was recorded. Daytime was defined as 9 AM to 9 PM and nighttime as 10 PM to 6 AM. Level of consciousness was quantified by the Glasgow Coma Scale (GCS) and neurologic deficit by the Scandinavian Stroke Scale (SSS). Patients were asked whether they were smokers or snorers, and their personal judgment was taken (as yes or no) as sufficient evidence to determine smoking and snoring status. Nursing staff were asked to record whether the patient was awake or asleep during the day and night study periods on an observation chart. None of the patients were asked to wake up from sleep to have blood pressure, respiratory