ACUTE EFFECTS OF OBSTRUCTIVE SLEEP APNOEA

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The pharyngeal airway narrows when pharyngeal muscle tone decreases. During sleep, partial collapse at this level leads to snoring, and complete collapse to obstructive sleep apnoea [25]. Such upper airway incompetence is relatively common: 17% of randomly selected normal British men snore [60]; one in 300 have severe obstructive sleep apnoea and cannot maintain a patent airway in any sleeping posture [60]. In hospital inpatient cohorts the prevalence is greater still. In one middle-aged group awaiting tonsillectomy more than 50% have some obstruction [29] and pharyngeal masses [66] also has been noted. In children, large tonsils and adenoids are the usual reason for sleep apnoea, and among children with ischaemic heart disease, significant obstructive sleep apnoea affected 14% of the sample [30].

Obstructive sleep apnoea has a range of undesirable acute effects which may be avoided by appropriate management. This review considers the causes of upper airway collapse, its consequences and treatment for the patient in hospital.

Aetiology of upper airway collapse during sleep

The patency of the muscular pharynx depends on the balance of forces acting across the pharyngeal wall. Muscle tone widens the airway, while external pressure from the peripharyngeal tissues, combined with intraluminal negative inspiratory pressures, narrow it. Any factor which adversely affects this balance tends to provoke airway collapse. Increased peripharyngeal soft tissue reduces sleeping airway calibre, probably through a simple mass effect [38]. In adults, neck fat deposition is the commonest factor predisposing to obstructive sleep apnoea; the circumference of the neck is a simple predictor of those at risk [13]. Internal airway narrowing as a result of retrognathia [49], adenotonsillar hypertrophy [61], craniofacial abnormalities [5, 33], nasal obstruction [29] and pharyngeal masses [66] also has a role. In children, large tonsils and adenoids are the usual reason for sleep apnoea, and among children awaiting tonsillectomy more than 50% have some respiratory disturbance during sleep [61]. Finally, a reduction in upper airway muscle tone caused by neuromuscular blocking drugs, sedatives [19, 44] and some antihypertensive drugs [41] exacerbates airway incompetence. This reduction in tone also underlies the widely recognized association between alcohol intake, snoring and obstructive sleep apnoea [31, 54, 63]. Similar effects have been shown for benzodiazepines [19, 44]. Neuromuscular diseases also may cause obstructive sleep apnoea through reductions in upper airway tone [20].

In hospital, several influences conspire to worsen any tendency to upper airway collapse. Hypnotic, analgesic and sedative drugs are often necessary, and are used to minimize sleep deprivation, which itself worsens sleep apnoea [24]. Patients may be obliged to sleep in a supine position because of the presence of i.v. and urinary catheters, monitors, and so on. This posture is the worst for those at risk of airway collapse, and about one in 50 men develop obstructive sleep apnoea in this position [60].

Identifying patients at risk of obstructive sleep apnoea

In adults, obstructive sleep apnoea should be suspected in those who snore and report daytime sleepiness [25]. There may also be a history of sleep apnoea witnessed by a partner [11]. Physical signs are less helpful. In adults who report snoring and sleepiness, a neck circumference greater than 43 cm (17 inches) suggests sleep apnoea is likely [13], and retrognathia or a small crowded pharynx supports the diagnosis. In children, sleepiness is combined with hyperactivity and antisocial behaviour [22], snoring is usual and large tonsils and adenoids are generally present [22]. When possible, suspected sleep apnoea should be documented with a sleep study before a hospital admission which may exacerbate the condition. However, for many patients this is not possible, and diagnosis is made only when the characteristic repetitive apnoeas are observed: the sleeping patient stops breathing (and making respiratory sounds), but continues to make respiratory efforts. The apnoea usually lasts for about 30 s, although pauses of up to 1 min may occur. At the end of this period, ventilation restarts suddenly as the pharynx reopens at arousal; often, but not always, this is associated with a loud snort and subsequent snoring. The ventilatory phase usually lasts about 15 s and is often associated with body movements.

The main clinical differential diagnosis to be made is with Cheyne–Stokes respiration resulting from unstable ventilatory control [36]. During typical Cheyne–Stokes respiration, the frustrated inspiratory efforts are absent, ventilation waxes and wanes smoothly, and the sound of pharyngeal opening at Br. J. Anaesth. 1993; 71: 725-729

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the return of inspiration is absent. Arousal from sleep and movement are seen during the ventilatory phases of both abnormalities [15, 25, 27]. Although it is usually possible to decide which abnormality is responsible for the periodic breathing, this may be difficult. Some patients with apnoea initiated by upper airway collapse make minimal respiratory efforts during the apnoea [32]; secondary upper airway collapse is common during Cheyne-Stokes respiration [2]. In difficult subjects, a trial of nasal continuous positive airway pressure to ensure upper airway patency may be needed to resolve the issue.

Adverse effects of sleeping upper airway obstruction

The adverse effects of obstructive sleep apnoea may be classified into two groups: the apnoea–arousal–ventilation cycle has substantial effects on haemodynamics, autonomic tone and arterial blood-gas tensions; and sleep disruption and vascular instability cause long-term morbidity and mortality.

Acute effects of obstructive sleep apnoea

Subjects with severe obstructive sleep apnoea exhibit a repetitive apnoea–arousal cycle during all stages, and in all positions adopted during sleep. A typical night may include 300–400 such events. Each apnoea causes haemodynamic instability, hypoxaemia, mild hypercapnia and marked autonomic disturbance.

The haemodynamic changes are multifactorial. The frustrated inspiratory efforts of repeated apnoea decrease arterial pressure–pulsus paradoxus [43]. As the apnoea extends, increasing asphyxia makes these ventilatory efforts increasingly vigorous [25], and the related decreases in arterial pressure consequently larger [42]. The inspiratory efforts reduce pleural pressure, which increases left ventricular afterload [35] and reduces left ventricular emptying. At the same time, the decrease in pleural pressure results in an increase in right atrial transmural pressure, accompanied by increased venous return [26]. The increase in atrial transmural pressure stimulates release of atrial natriuretic peptide, which probably causes the sleeping natriuresis of untreated obstructive sleep apnoea [39]. In normal supine man, the increase in venous return caused by the decreases in pleural pressure may be limited by the collapse of the major veins carrying blood into the thorax [10, 46]. The increased venous return that does occur distends the right ventricle, which reduces left ventricular compliance [65]. This impairs left ventricular filling and ejection. Finally, changes in intrathoracic pressure alter lung blood content in a way which is difficult to predict if the lung volume changes [8]. However, during obstructive sleep apnoea lung volume is fixed, the airway blocked and decreases in pleural pressure are mirrored by decreases in alveolar pressure. In this situation, lung blood volume probably increases [8].

At the end of an obstructed inspiratory effort, these effects are reversed. One obstructive apnoea includes a series of transient inspiratory efforts; how much recovery occurs between efforts is uncertain, and probably varies between subjects. These opportunities for recovery are often overlooked, and one apnoea is discussed as if it were a single sustained Müller manoeuvre. In support of this assumption, a progressive leftward shift in the ventricular septum occurs throughout an apnoea [58], although this may be the result of a progressive increase in right ventricular afterload caused by hypoxic pulmonary artery vasoconstriction. Left ventricular end-diastolic and pulmonary capillary wedge pressures also increase throughout an apnoea [9] and cardiac output decreases [23, 65]. After an episode of apnoea, an increase in arterial pressure occurs [55]; the reversal of the haemodynamic effects of the apnoea period and the consequent release of a bolus of blood from the thorax probably contribute to this.

Superimposed on the mechanical effects of the obstructed inspiratory efforts are the actions of hypoxia and hypercapnia. Hypoxia contributes directly to apnoeic bradycardia [70] and arrhythmias [56] and may also have a role in the apnoea-related increases in arterial pressures [55], although this is controversial. It is clear that the apnoea-induced nadir in arterial oxygen saturation coincides with the peak of the post-apnoeic increase in arterial pressure and correlates with its magnitude [4, 55]. Furthermore, obstructive sleep apnoea simulated during wakefulness causes arterial pressure changes which are attributable to hypoxia [1]. However, it is not clear that this effect persists during sleep. Two recent studies have corrected the arterial desaturation of obstructive sleep apnoea with supplementary oxygen without halting the apnoea–arousal cycle [4, 52]. In both these studies, abolishing hypoxaemia did not alter the magnitude of the increase in arterial pressure after the apnoeic episode. Furthermore, sleeping hypoxaemia as severe as that seen during obstructive sleep apnoea, but produced without apnoea or arousal, does not cause an increase in arterial pressure [52].

Hypercapnia also is unlikely to be a major contributor to the haemodynamic instability of obstructive sleep apnoea, as the changes in arterial partial pressures of carbon dioxide are small. After apnoea with airway closure, the alveolar partial pressure of carbon dioxide equilibrates with mixed venous values within one circulation time—less than 1 min [47]. Assuming normal indices before apnoea, this leads to an increase in the arterial partial pressure of carbon dioxide from 5.3 to 6.1 kPa; thereafter the value increases by about 0.4–0.8 kPa min⁻¹ [47], reflecting changes in the total body carbon dioxide stores. Over 2 min, this increases the partial pressure by about 1.4 kPa. Typically, the obstructive sleep apnoea cycle lasts about 1 min, of which 25% comprises ventilation; an increase in $P_{ACO_2}$ of 1.4 kPa is thus an overestimate of the change that would be expected. In dogs, increasing $P_{ACO_2}$ by 1.4 kPa increases arterial pressure by only about 5 mm Hg [53]. The average post-apnoeic arterial pressure increase associated with obstructive sleep apnoea is about 20 mm Hg [55]; increases as great as 100 mm Hg may occur.

The third element of the obstructive sleep apnoea cycle which is capable of causing much of the post-apnoeic haemodynamic response is arousal from sleep at the end of apnoea [14]. Arousal from normal
sleep causes a range of responses which include skin vasoconstriction [69], increased heart rate [34], changes in skin resistance [34] and an increase in arterial pressure [14]. The magnitude of these responses varies with the duration of EEG arousal [14], and does not habituate with repetition [34, 69]. Together, these responses have been termed the orienting reflex [34]. The magnitude of the arterial pressure response to arousal from normal sleep may be similar to that observed with arousal during obstructive sleep apnoea [14], and is preserved in obstructive sleep apnoea patients who have been treated effectively with nasal continuous positive airway pressure [52]. Further support for an important contribution from arousal comes from sleep disruption syndromes which include arousal and cause changes in arterial pressure, but which lack other features of obstructive sleep apnoea. In central sleep apnoea, periodic ventilation and arousal occur without obstructed respiratory efforts [25] and in periodic movements of the legs, recurrent arousal occurs without any ventilatory respiratory abnormality [43]. Both these syndromes cause changes in arterial pressure similar to those of obstructive sleep apnoea [3, 12].

Obstructive sleep apnoea is also associated with substantial autonomic nervous system activation. During each period of apnoea there is a progressive increase in peripheral neural sympathetic [28] and cardiac vagal [64] activity, which terminates abruptly at the resumption of breathing [28]. Urine catecholamine concentrations are increased markedly at night, and probably abnormal also during the day—changes which resolve with effective treatment [17].

**Chronic effects of obstructive sleep apnoea**

The long-term adverse effects of obstructive sleep apnoea are the result of sleep disruption and cardiorespiratory disease. The 300 or more arousals which occur during every night of severe obstructive sleep apnoea severely fragment sleep and cause marked daytime sleepiness [25]. Tasks which require sustained vigilance (particularly driving) are badly affected—untreated sleep apnoea sufferers are 5–10 times more likely than normal individuals to be involved in road traffic accidents [16, 18]. The heavy snoring at night and daytime hypersomnolence cause significant social distress, and the inability to remain awake at work may lead to loss of employment.

A small minority of obstructive sleep apnoea patients with another respiratory impairment develop daytime respiratory failure and cor-pulmonale [40]—the “Pickwickian Syndrome”. In adults, the associated respiratory abnormality is usually chronic obstructive lung disease [7, 40], although a restrictive lung defect from morbid obesity and neuromuscular weakness are other possibilities. In this situation, provided the second respiratory illness is not itself severe, respiratory failure improves when the obstructive sleep apnoea is treated effectively [6]. Children may also develop pulmonary hypertension [68] and perioperative deaths from cor-pulmonale as a result of obstructive sleep apnoea have been reported after adenotonsillectomy [68].

Untreated adult obstructive sleep apnoea is associated with vascular death [48], daytime hypertension [21] and coronary artery disease [30]. However, interpretation of these associations is complex because patients with obstructive sleep apnoea and snoring tend to be obese and have large intakes of tobacco and alcohol. Relatively few studies have corrected adequately for these confounding variables [59, 67].

**TREATMENT OF OBSTRUCTIVE SLEEP APNOEA**

Pharyngeal and craniofacial surgery [51, 57], tracheotomy [48] and weight loss [48] have all been used in the chronic management of obstructive sleep apnoea. However, nasal continuous positive airway pressure [62] has recently become the mainstay of adult chronic management, and is also appropriate for the hospital inpatient with obstructive apnoea not corrected by changing from a supine posture. Increasing the inpharyngeal airway pressure forces the airway open by acting as a pneumatic splint [50]; this corrects the apnoea [62], the associated snoring [62] and the cardiovascular and autonomic instability [4]. A nasal mask may be used, which is less claustrophobic than a full face mask, although in some subjects a substantial mouth leak necessitates a chin support. Side effects of this treatment are few. Nasal obstruction and rhinorrhea may occur, but usually respond to nasal decongestants. Cardiac output may decrease when airway pressure is increased [37], and this should be considered when patients with severe cardiac disease are treated.

Hospital inpatients who have previously been treated for obstructive sleep apnoea should continue their usual treatment during their admission. Many will have their own nasal continuous positive airway pressure machine which can be brought into hospital. These machines are light and portable, and require only a mains power supply. Supplementary oxygen may be added to the nasal mask if needed, although this delivers an unpredictable inspired concentration of oxygen. The continued use of continuous positive airway pressure is particularly important if substantial haemodynamic lability is disadvantageous, such as after vascular surgery.

Oxygen therapy alone is inadequate treatment. Sleep apnoea-induced hypoxaemia may be corrected in this way [4, 52], but many of the other effects are not returned to normal. The disturbances in pleural pressure, cardiac preload and afterload, heart rate, arterial pressure and sleep structure, all persist unless airway patency is maintained [4, 52].

Subjects who require treatment for obstructive sleep apnoea during an acute illness or perioperatively should all be assessed for persisting apnoea after their recovery. A proportion of these subjects may have continuing problems which require appropriate long-term management.

**CONCLUSION**

Obstructive sleep apnoea is a common disorder. About one in 50 men have some upper airway obstruction when lying supine, and this is worse...
under the provocation of sedative or neuromuscular blocking drugs. Untreated obstructive sleep apnoea produces potentially disadvantageous blood-gas, haemodynamic and autonomic changes, all of which are corrected with continuous positive airway pressure. Awareness of obstructive sleep apnoea is needed among medical staff treating acutely ill hospital patients.

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REFERENCES


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