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Pronounced, Episodic Oxygen Desaturation in the Postoperative Period: Its Association with Ventilatory Pattern and Analgesic Regimen

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The respiratory effects of two postoperative analgesic regimens were compared in two groups of 16 patients each, recovering from general anesthesia and major surgery. One group received a pain-relieving dose of iv morphine (mean, 18.1 mg), with the same dose repeated as a continuous intravenous infusion over the subsequent 24 h. The other group received regional anesthesia using bupivacaine. The patients were monitored for 16 h after surgery. The two analgesic regimens provided patients with comparable analgesia throughout the study period, but there were quite different respiratory effects in the two groups. Ten patients receiving morphine infusions had a total of 456 episodes of pronounced oxygen desaturation ($SaO_2 < 80\%$). These occurred only while the patients were asleep, and all were associated with disturbances in ventilatory pattern, namely, obstructive apnea (144 episodes in eight patients), paradoxic breathing (275 episodes in six patients), and period of slow ventilatory rate (37 episodes in one patient). In contrast, in patients receiving regional anesthesia, oxygen saturation never decreased below 87%. Central apnea, obstructive apnea, and paradoxic breathing occurred more frequently in patients in the morphine group (12, 10, and 10 patients, respectively) than patients in the regional anesthesia group (4, 3, and 5 patients, respectively). The interaction of sleep and morphine analgesia produced disturbances in ventilatory pattern, causing profound oxygen destruction. These results suggest that postoperative pain relief using regional anaesthesia has a greater margin of safety in terms of respiratory side effects than does the continuous administration of opiates. (Key words: Analgesia: postoperative. Analgesics: morphine. Anesthetic techniques: epidural; regional; intercostal. Hypoxia: postoperative. Ventilation: apnea; pattern.)

IT IS GENERALLY BELIEVED that the important respiratory side effects of opiate analgesics are slow ventilatory rate and diminished minute volume and that these abnormalities are easily recognized on *intermittent* observation by nursing or medical staff.

During a postoperative study comparing the respiratory effects of continuous and intermittent opiate analgesia, Catling *et al.*[1] used *continuous* respiratory monitoring techniques to demonstrate unpredictable and short-lived disturbances in ventilatory patterns. These were attributed to the effects of narcotic analgesic drugs and were not noticed with the use of intermittent observation. Similar ventilatory disturbances frequently are associated with profound and potentially life-threatening hypoxemia in patients with sleep apnea syndrome.[2-4] Anesthesia and surgery commonly produce a background of mild hypoxemia in the postoperative period[5-7] such that episodes of apnea may result in profound decreases in arterial oxygen tension.

In this study we have examined the relationship between postoperative disturbances in ventilatory pattern and the arterial oxygen saturation. We have also established whether these disturbances are the result primarily of narcotic analgesia or due to the postoperative effects of general anesthesia and surgery. This was achieved by studying two analgesic regimens, namely continuous morphine infusion and regional anesthesia. Because respiratory patterns are known to be profoundly influenced by sleep,[8] and the depressant properties of narcotic analgesics are enhanced by sleep,[9] we also examined the association between respiratory disturbances and sleep.

Materials and Methods

PATIENT SELECTION

Thirty-two patients undergoing elective cholecystectomy (using a Kocher's incision) or total hip replacement gave their informed consent to the study, which was approved by the Hospital Ethical Committee. They were allocated to one of two groups. One group received a continuous intravenous infusion of morphine, and the other group received regional anesthesia using bupivacaine (either lumbar extradural or intercostal nerve block). The two groups were matched for age, weight, height, and type of surgery.

On the evening before surgery, patients were visited by one of the investigators to ensure that they were nonsmokers and free from cardiorespiratory disease, that they were a low anesthetic risk (ASA I or II), and

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that they were not obese, *i.e.*, they had a weight/height squared ratio of between 19 and 25, a range that is associated with minimal mortality.[10] After this preliminary screening, patients were taken to the room where the studies were to be conducted.

Instruments and Calibration

The breathing pattern was measured continuously using a respiratory inductive plethysmograph (RIP) that consisted of two transducer bands worn around the rib cage and abdomen. The transducers measured changes in cross-sectional area virtually independent of the shape of the torso.[11] The signals from the two transducers were electronically summed to give a third signal that was proportional to tidal volume. Once the patient had been familiarized with the recording apparatus, it was calibrated as follows. All three signals were calibrated in terms of volume change by the supine patient performing an isovolume maneuver[12] and then breathing into a spirometer (Ohio Ltd., Model 840). The calibration procedure was repeated at least twice in the postoperative period. This method of calibration has been shown[12] to provide accurate (error < 7%) RIP measurements of tidal volume over the range 0.25–1.25 l.

After calibration of the RIP transducer, an ear oximeter[13,14] was attached to the patient, and recordings of oxygen saturation (Sa_{O_2}) and ventilatory pattern were made for 30 min on a chart recorder (SLE 10/8) and on magnetic tape (Racal®, Store 4 tape recorder). The chart recording was inspected to ensure that ventilatory movements of rib cage and abnormal signals were in phase and that Sa_{O_2} did not fall below 96%. Any patient not fulfilling these criteria was excluded from the study. Once this assessment was complete, the position of the two RIP transducer bands was marked on the skin. The bands then were removed and the patients returned to the ward until surgery the following morning.

Anesthesia

Preoperative opiate medication (papaveretum 0.13–0.26 mg/kg im and atropine, 0.005–0.011 mg/kg im) was given 1 h prior to surgery. If the patient had been allocated to receive extradural anesthesia postoperatively, a lumbar catheter was inserted on arrival at the operating room. Anesthesia was induced with thiopentone (2.1–6.9 mg/kg iv) followed by pancuronium (0.075–0.133 mg/kg) and the patient was then intubated and ventilated with 33% oxygen in nitrous oxide and enflurane (0–1.5%). No opiate drugs were given intraoperatively unless the patient had been allocated to receive a morphine infusion, in which case they were given 0.04 mg/kg morphine iv on skin closure. At the end of surgery, neuromuscular blockade was reversed with neostigmine (2.5 mg) and atropine (1.0–1.2 mg). This event was taken as time zero for the study. Once spontaneous ventilation had been reestablished the patients were extubated and taken to the recovery area where they received 28% supplementary oxygen via a Ventimask® for 2–3 h. Oxygen saturation was recorded subsequently when the patients were breathing air.

Postoperative Analgesia

On regaining consciousness and reporting pain, patients allocated to receive an infusion were given morphine intravenously at a rate of 1 mg/min (the "loading" dose) until they stated that the pain was appreciably reduced. The loading dose of morphine injected was repeated as a continuous intravenous infusion over the subsequent 24 h. This infusion rate could be increased if the patient complained of inadequate analgesia. Patients allocated to receive regional anesthesia were given a lumbar extradural injection of bupivacaine (Marcaine®, 8 ml, 0.25% plain) after a total hip replacement or an intercostal nerve block from T6 to T10 inclusive using bupivacaine (4 ml, 0.5% with epinephrine), after a cholecystectomy. Both blocks were renewed as required with "top up" doses of bupivacaine.

Postoperative Measurements

Pain scores were obtained using a 10-cm linear analog scale.[15] Pain severity was also assessed using a five-point verbal rating score. Postanalgesia pain scores were taken at 3–4 h intervals when the patient was awake.

Once postoperative analgesia had been given the patient was transferred to the study room where the RIP transducers were replaced and aligned with the skin markings made during the calibration procedure.

Continuous measurements of ventilation, oxygen saturation, electroencephalograms (EEG), electro-oculograms (EOG), and EKG were then made for at least 16 h.

Data Analysis

Ear oximetry recordings were analyzed for periods of desaturation, in excess of 5 s where the oxygen saturation decreased below 80% (equivalent arterial oxygen tension of approximately 45 mmHg or 6 kPa). All such recordings were made only with the patient breathing air. The RIP recordings were examined for five different types of ventilatory disturbance: 1) central apnea, defined as a period in excess of 10 s where all respiratory efforts ceased as indicated by negligible rib cage, abdominal, and tidal volume (RIP) signals[2]; 2) obstructive apnea, defined as a period in excess of 10 s where there was a negligible tidal volume (RIP) signal

TABLE 1. Mean (+SD) Age, Weight, Height, and, where Relevant, Loading Dose of Morphine of Postoperative Patients in the Two Analgesic and Surgical Groups.

	Morphine Analgesia		Regional Anesthesia	
	Cholecystectomy (n = 8)	Total Hip Replacement (n = 8)	Cholecystectomy (n = 8)	Total Hip Replacement (n = 8)
Age (yr)	57.9 ± 11.8	62.6 ± 8.6	58.1 ± 11.0	61.9 ± 8.7
	(41–72)	(50–72)	(43–73)	(49–72)
Sex	4M, 4F	3M, 5F	4M, 4F	2M, 6F
Weight (kg)	65.3 ± 7.5	66.5 ± 8.2	66.9 ± 4.4	67.0 ± 8.2
	(54–75)	(57–80)	(60–74)	(58–78)
Height (m)	1.70 ± 0.1	1.67 ± 0.1	1.71 ± 0.1	1.73 ± 0.1
	(1.63–1.75)	(1.50–1.78)	(1.68–1.78)	(1.58–1.85)
Loading dose	21.2 ± 12.8	14.9 ± 4.5	—	—
(mg morphine)	(6–47)	(8–22)	—	—

Ranges in parentheses.

despite the rib cage and abdominal (RIP) signals showing persistent out-of-phase respiratory movements[2]; 3) paradoxic breathing, defined as a period of 5 min where over 50% of the breaths displayed out of phase rib cage and abdominal signals in excess of 50 ml volume; 4) slow respiratory rate, defined as a 5-min period where the respiratory rate was less than 10 breaths/min for 50% of that period; 5) small tidal volumes, defined as a 5-min period where over 50% of the breaths were less than 300 ml and all the breaths were less than 400 ml.

Sleep stage was assessed using the scoring criteria of Rechtschaffen and Kales,‡ but because patients' sleep patterns were characterized by rapid changes between the lighter planes of sleep the following three categories of sleep state were defined in this study. Sleep stage 0 was defined as "awake," sleep stage 1 or stage 1 progressing to stage 2 was defined as "transitional" sleep, and sleep stages 2, 3, 4 and REM were defined as "asleep." The amount of stages 2, 3, 4 and REM sleep was noted, however, with the use of conventional scoring criteria.

Results

Patient Population and Anesthesia

The distribution of the 32 patients between the two analgesic regimens and the two surgical groups is shown in table 1, together with their demographic data. No statistically significant differences (one-way analysis of variance) were found between the four groups with respect to age, weight, or height. None of the patients were clinically obese, the range of weight/height squared ratios[10] being between 19.7 and 25.0.

Surgery and anesthesia were uncomplicated in all 32 patients. There was no difference in the duration of anesthesia in the two analgesic groups, the mean (±SD) duration being 141 ± 44 min for the 16 patients who received morphine infusion and 140 ± 56 min for the 16 patients who received regional anesthesia. Not surprisingly, there was a difference in the mean duration of anesthesia for the 16 patients undergoing total hip replacement (171 ± 35 min) when compared with the 16 patients undergoing cholecystectomy (110 ± 43 min).

Analgesia and Pain Scores

The loading doses of morphine given on recovery from anesthesia are shown in table 1. Infusion rates ranged between 0.25 and 1.95 mg/h, with an overall mean rate of 0.76 ± 0.41 mg/h. The loading doses and infusion rates tended to be greater in patients recovering

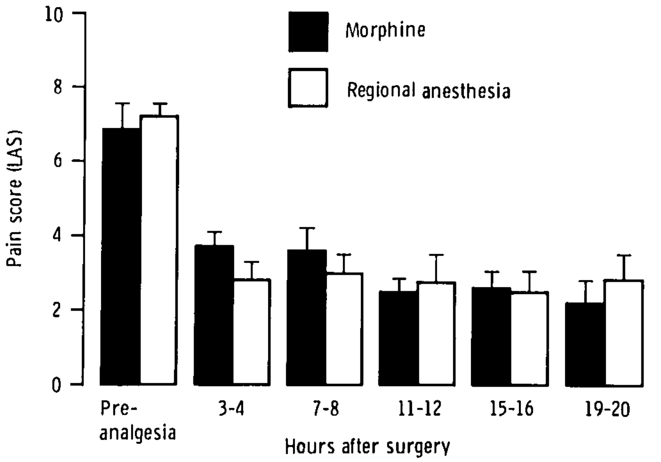

FIG. 1. Mean pain scores (±1 SEM) obtained using linear analog scales (LAS) in patients receiving morphine infusions (n = 16) and patients receiving regional anesthesia (n = 16). Preanalgesia pain scores are means from seven patients in each of the two analgesia groups.

‡ Recthschaffen A, Kales A (eds): A manual of standardised terminology, techniques and scoring systems for sleep stages in human subjects. Washington D.C., Public Health Service, U.S. Government Printing Office, 1968.

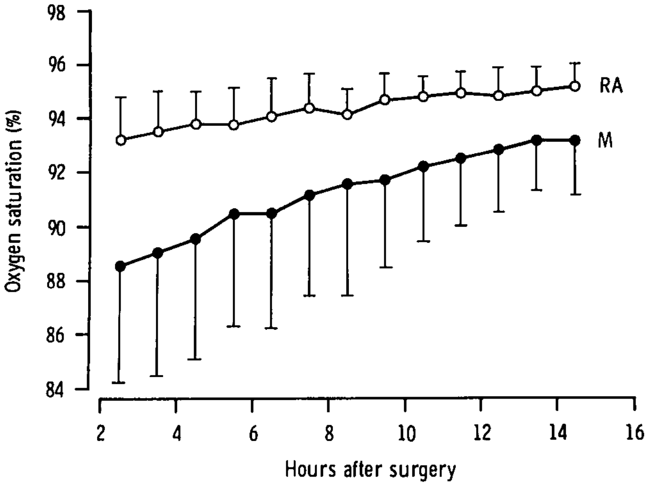

FIG. 2. Mean (±1 SD) hourly arterial oxygen saturations in patients receiving morphine infusions (M, closed circles) and patients receiving regional anesthesia (RA, open circles). Mean (±1 SD) preoperative saturations in the two analgesia groups were 96.7 ± 0.6% and 96.9 ± 0.3%, respectively.

TABLE 2. The Incidence of Hypoxemia (Sa_{O_2} < 80%) in the First 16 h after Surgery while Patients Were Breathing Room Air

	Cholecystectomy	Total Hip Replacement
Morphine group (16 patients)		
Number of patients	4	6
Number of episodes	220	236
Regional anesthesia group (16 patients)		
Number of patients	0	0
Number of episodes	0	0

A total of 456 episodes of pronounced desaturation (Sa_{O_2} < 80%) were recorded in 10 patients. These episodes lasted between 5 and 120 s and were seen only in patients who received morphine infusions (table 2). The incidence of desaturation was similar in patients after hip replacement or cholecystectomy.

The incidence of desaturation recorded in patients receiving morphine decreased as the postoperative period progressed (fig. 3), and there was a significant difference from cholecystectomy than in patients recovering from total hip replacement, although differences were not statistically significant (one-way analysis of variance).

The mean pain scores (linear analog scales) are shown in figure 1. There was little difference between pain scores in the morphine group compared with the regional anesthesia group, and therefore arc–sine transformations and statistical tests were not performed on these data. Pain scores also were found to be similar between patients after hip replacement and those after cholecystectomy. Verbal rating scores confirmed these observations. On questioning, 48 h after surgery, none of the patients said their postoperative analgesia had been inadequate, but they all said there was room for improvement—no patient reported complete pain relief.

OXYGEN SATURATION RECORDINGS

Satisfactory continuous recordings of arterial oxygen saturation were made in all 32 patients breathing air. These recordings were used to obtain a mean hourly oxygen saturation for the two groups of patients by excluding transient decreases in Sa_{O_2} (fig. 2). There was a significantly different trend with time in the morphine group compared with the regional anesthesia group ($P < 0.001$; repeated measure analysis of variance[16]). Throughout this 16-h recording period, the mean "baseline" Sa_{O_2} for the morphine patients was consistently lower than the Sa_{O_2} in patients receiving regional anesthesia. No correlation could be found between baseline oxygen saturation and the duration of anesthesia, the loading dose of morphine or the incidence of pronounced desaturation.

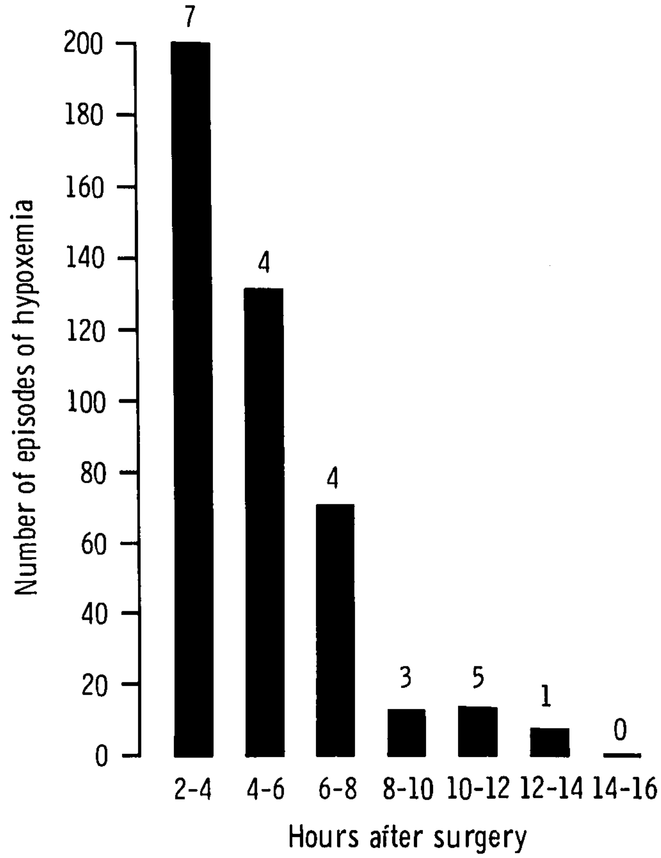

FIG. 3. Histogram showing the total number of episodes of hypoxemia in patients receiving morphine infusions against time after the end of anesthesia. There were no episodes of hypoxemia in patients receiving regional anesthesia. Numbers on top of each column refer to the number of patients with hypoxemic episodes.

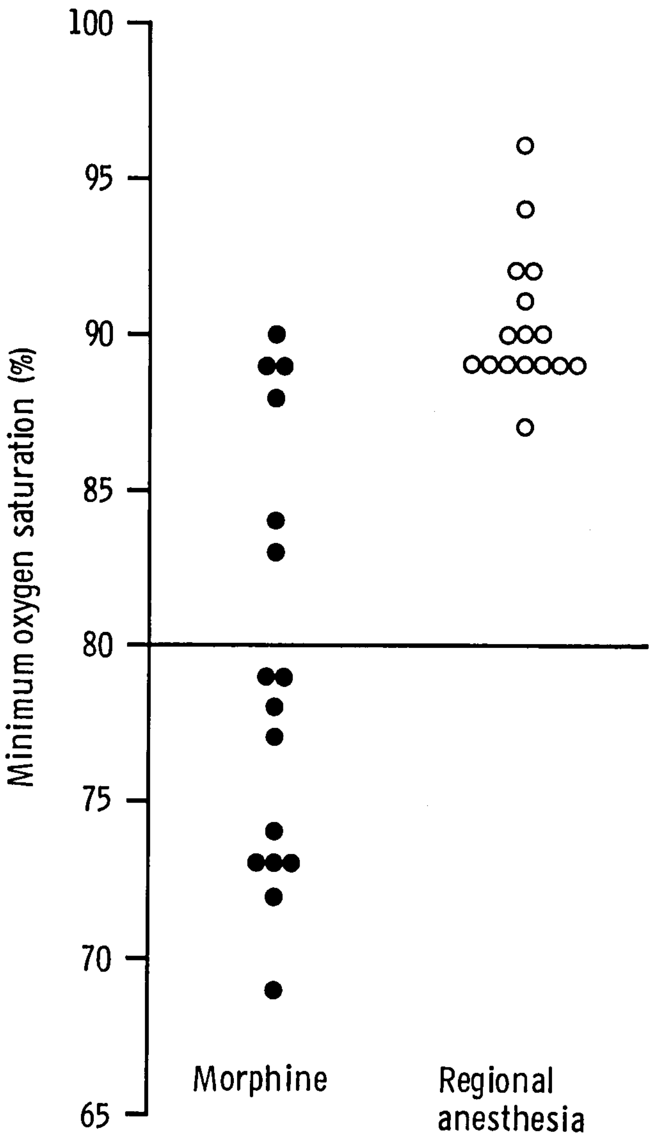

FIG. 4. Individual minimum oxygen saturations recorded in the first 16 postoperative hours in patients receiving morphine infusions (closed circles) and patients receiving regional anesthesia (open circles).

between the lowest oxygen saturations of these patients and those patients receiving regional anesthesia (fig. 4, $P < 0.01$, Mann-Whitney U test).

VENTILATION DISTURBANCES

Satisfactory RIP recordings were made in all 32 patients. All postoperative RIP calibration factors were found to be within 10% of the original preoperative values.

All five types of ventilatory disturbance tended to be more common in patients receiving morphine (fig. 5). The number of patients with central and obstructive apnea were significantly different in the two analgesia groups ($P = 0.012$ and $P = 0.029$, respectively, Fisher's exact test), whereas there were no significant differences in the incidence of any of these disturbances between patients after cholecystectomy or patients after hip replacement, and there was no correlation between "baseline" oxygen saturation and the incidence of ventilatory disturbances.

While central apnea could occur in isolation from other ventilatory disturbances, 10 of the 12 patients who had episodes of obstructive apnea also had episodes of central apnea and paradoxic breathing.

The distribution of the five types of ventilatory disturbance in the two analgesia groups is shown in Figure 5. The incidence of central apnea and episodes of slow respiratory rate decreased as the postoperative period progressed (fig. 6). In contrast, the other ventilatory disturbances showed no clear trends, although the incidence of obstructive apnea tended to increase at 10–12 h after surgery.

The incidence of respiratory disturbances increased with age (fig. 7). This was particularly apparent in the patients aged 66–75 yr who received morphine infusions.

OXYGEN DESATURATION, VENTILATORY DISTURBANCE, AND SLEEP STAGE

Pronounced oxygen desaturation and obstructive apneas *never* occurred while the patients were awake. It was also rare to see episodes of paradoxic breathing while the patients were awake.

The relationship between ventilatory pattern and episodes of pronounced oxygen desaturation is shown in table 3. Nearly all the desaturations, seen only in the morphine group, were associated with obstructive apnea or paradoxic breathing. Episodes of slow respiratory rate were associated with desaturation in only one patient. It was noticeable that while central apneas were frequently preceded by signs of EEG arousal and an episode of transient hyperventilation, the onset of obstructive apnea was often the climax to an episode of paradoxic breathing. The end of an episode of obstructive apnea was also frequently associated with signs of EEG arousal.

Table 4 shows the relationship between respiratory disturbances and the sleep stage at the time of the disturbance. Because episodes of paradoxic breathing, slow respiratory rate, and small tidal volumes were scored in 5-min epochs, the sleep stage frequently changed during these events. This made it difficult to summarize the sleep stage during such events, and they were therefore not included in table 4.

Only one of the patients in this study went into REM sleep during the 16-h study period. Stage 3 and stage 4 sleep were observed only in one patient.

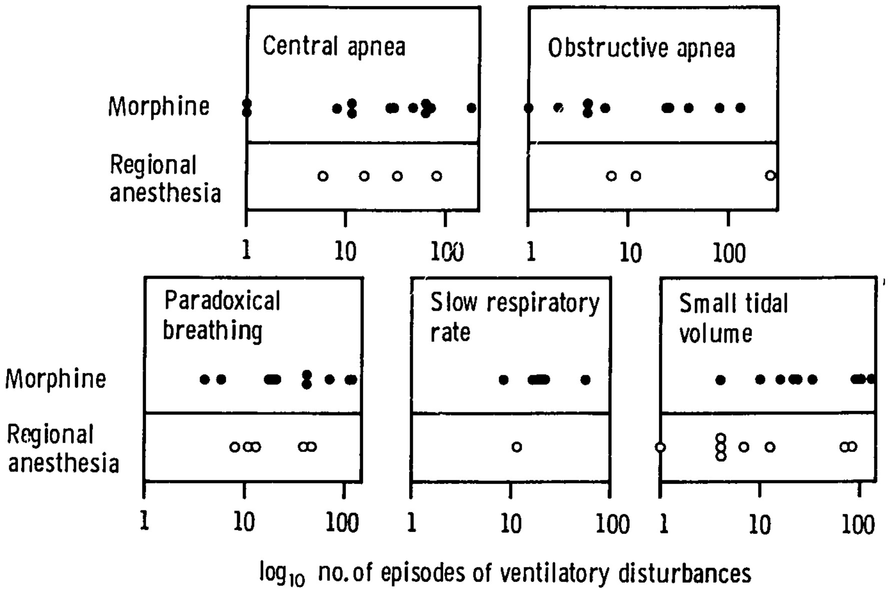

FIG. 5. Frequency distribution of the numbers of episodes of ventilatory disturbances in patients receiving morphine infusions (closed circles) and patients receiving regional anesthesia (open circles). Note number of episodes (x-axis) is a logarithmic scale.

Discussion

Oxygen Desaturation

The most striking finding of this study was the high incidence of episodes of pronounced (<80%) oxygen desaturation, associated with disturbances in ventilation, observed only during sleep and only in the group of patients receiving morphine infusions (table 2). These patients were apparently making an uneventful recovery from anesthesia and surgery.

In "healthy" patients[5-7,17] oxygen tensions, during the first postoperative day following major surgery, have been found to decrease to 60–75 mmHg (Sa_{O_2} < 85–90%). Therefore, a decrease in oxygen saturation below 80% would be exceptional and worthy of comment. Furthermore, because of the shape of the oxyhemoglobin dissociation curve, oxygen tension starts to decline rapidly once saturation has decreased below 85%. As figure 4 shows, none of the patients receiving regional anesthesia had oxygen saturations below 86%, despite the fact that the group had comparable pain relief during the study.

The lower oxygen saturations in patients receiving morphine are probably a reflection of the respiratory depressant property of narcotic analgesic drugs,[18-20] which is avoided by using regional anesthesia for pain relief.[5] Unlike other investigators,[5,6] we found that oxygen saturation in both analgesia groups gradually increased postoperatively over the first 16 h, although values did not return to their preoperative levels during this period (fig. 2). This finding may be a consequence of the dose regimen used for patients receiving morphine, rather than being directly related to the administration of morphine by continuous infusion.

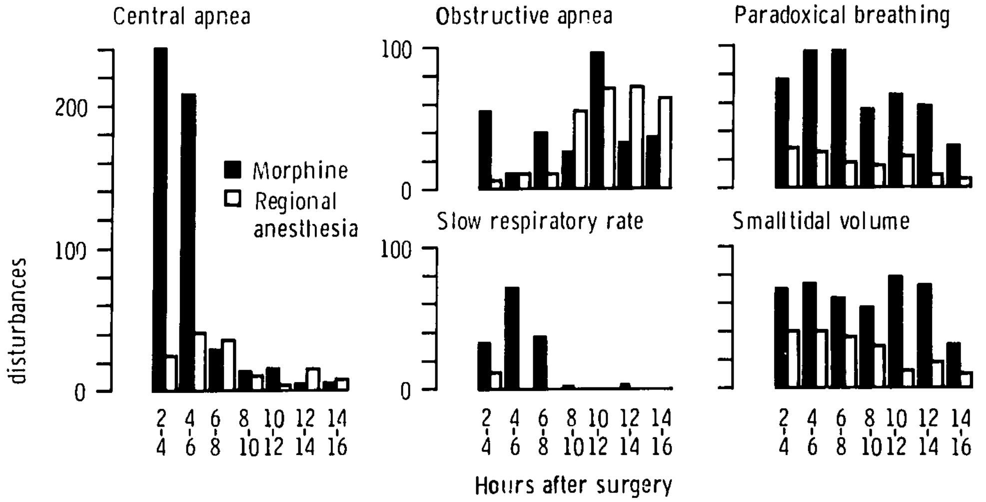

FIG. 6. Histograms showing the total number of episodes of ventilatory disturbances against time after the end of anesthesia in patients receiving morphine infusions (closed columns) and patients receiving regional anesthesia (open columns).

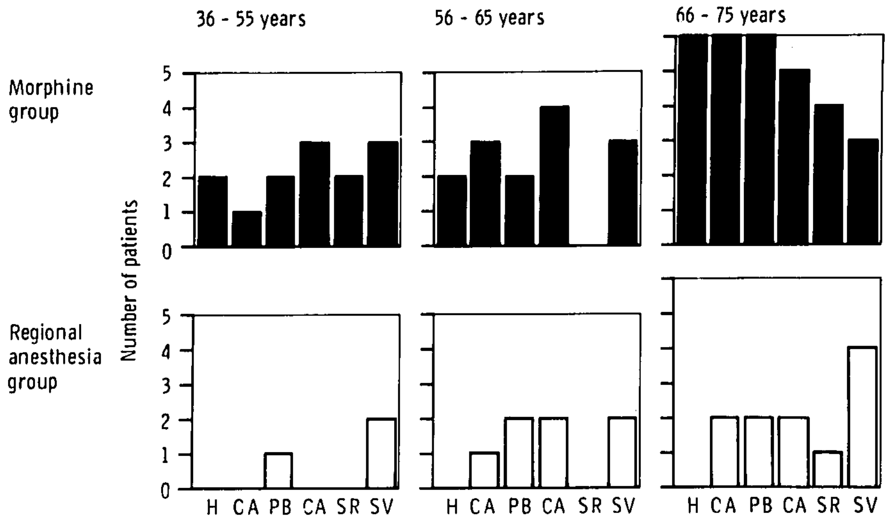

FIG. 7. The effect of age on the incidence of respiratory disturbances in patients receiving morphine infusions and patients receiving regional anesthesia. H = hypoxemia (Sa_{O_2} < 80%); OA = obstructive apnea; PB = paradoxic breathing; CA = central apnea; SR = slow respiratory rate; SV = small tidal volumes.

VENTILATORY PATTERN AND OXYGEN DESATURATION

The most common disturbances of ventilatory pattern seen in the present study were episodes of apnea. The strong association between apnea, paradoxic breathing, and type of analgesia (table 2) suggests that morphine can disrupt the respiratory pattern of postoperative patients as well as depress the chemical control of ventilation.[18] These disturbances in ventilatory pattern are not unique to the administration of morphine by continuous infusion. In a comparative study of the respiratory effects of continuous and intermittent papaveretum analgesia, Catling *et al.*[1] found disturbances of breathing pattern in both analgesic groups.

It is remarkable that nearly all of the episodes of pronounced oxygen desaturation were associated with paradoxic breathing or obstructive apnea (table 3). In contrast, central apneas were never associated with desaturation, even though they often lasted longer than periods of obstructive apnea. This difference is likely to be due to the fact that central apneas frequently occurred after a period of transient hyperventilation or during a period of otherwise normal ventilation, and therefore the oxygen saturation was relatively high at the start of the apnea. Obstructive apneas, however, were often preceded by a period of paradoxic breathing, during which time the patients frequently were heard to be snoring. As these episodes of inspiratory obstruction[21] progress, lung volume may decrease, producing a concomitant reduction in oxygen saturation.[22,23] The rate of decrease of oxygen saturation during the apnea is determined by the initial lung volume[23] and oxygen saturation[24] at the start of a period of apnea.

It was noticed that the incidence of pronounced oxygen desaturation (fig. 3), central apnea, and paradoxic breathing (fig. 6) decreased with time. This probably reflects the effect of the initial "loading dose" of morphine given at the start of the continuous infusion. However, during the early postoperative period the residual effects of anesthesia may also play a role in the disturbance of breathing patterns.

Seven patients in this study had periods of slow respiratory rate (<10 breaths/min), although this resulted in pronounced oxygen desaturation (<80%) in only one patient. This observation, together with the fact that oxygen desaturation generally occurred during periods of normal respiratory rate, suggest that intermittent measurements of respiratory rate alone are an insensitive indicator of the adequacy of ventilation in postoperative patients. In addition, the transient nature of ventilatory disturbances and oxygen desaturations highlights the need for continuous monitoring techniques when assessing respiration in the postoperative period.[25]

TABLE 3. The Relationship between Hypoxemic Episodes and Ventilatory Disturbances

Ventilatory Disturbance	No. of Patients	No. of Hypoxemic Episodes
Obstructive apnea	8	144
Paradoxical breathing	6	275
Slow respiratory rate	1	37
Central apnea	0	0
Small tidal volume	0	0

A total of 456 such episodes were recorded (see table 2), *only* in patients receiving morphine infusions.

SLEEP AND OXYGEN DESATURATION

All the disturbances in ventilatory pattern that resulted in pronounced oxygen desaturation in the morphine group occurred while the patients were asleep (table 4).

TABLE 4. The Relationship Between Sleep Stage and Episodes of Hypoxemia and Apnea

	Awake		Transitional		Asleep	
Respiratory Disturbance	No. of Patients	No. of Episodes	No. of Patients	No. of Episodes	No. of Patients	No. of Episodes
Hypoxemia	0	0	7	104	9	315*
Central apnea	14	113	12	185	12	347
Obstructive apnea	0	0	9	94	11	510

* Including 37 episodes of hypoxemia associated with periods of slow respiratory rate.

Patients who received regional anesthesia for pain relief had few disturbances in ventilation while asleep (table 2). This difference is notable because patients in the two groups had comparable total sleep durations. In healthy subjects sleep produces mild disturbances in arterial blood gas tensions and ventilatory patterns,[26,27] which probably result from alterations in the stimuli influencing ventilation[8,28] and a reduction in the sensitivity of the chemical control of ventilation.[29,30] These disturbances are a predominantly male related phenomenon[27] and are normally only associated with mild oxygen desaturation,[28] unless the subjects are obese.[31] In contrast, the ventilatory disturbances seen in the present study were frequently associated with pronounced oxygen desaturation, none of the patients were obese, and the different types of ventilatory disturbance were not sex related.

These observations imply that narcotic analgesia is an important cause of ventilatory disturbances during sleep in postoperative patients. Indeed, two patients receiving morphine analgesia who had 101 and 61 episodes of oxygen desaturation, respectively, during their first postoperative night were observed to have no such episodes when they were restudied on the 13th postoperative night while taking no opiate analgesics. Furthermore, the incidence of central and obstructive apneas (180 and 61 central, 1 and 133 obstructive, respectively) was 5 and 7 central apneas and no obstructive apneas, respectively, on the 13th night.

Sleep is known to depress the tonic and phasic activity of the musculature of the upper airway[32] and rib cage (intercostals)[33] more than that of the diaphragm. Morphine preferentially depresses the rib cage contribution to tidal volume, leaving the diaphragm contribution relatively constant.[34] If morphine affects the muscles of the upper airway in a fashion that is similar to the effects of sleep, then the drug may act synergistically with sleep to reduce the tone of the upper airway musculature. Loss of tone causes narrowing of the upper airway[35] and an increase in its airflow resistance.[36] This can lead to snoring, paradoxic breathing, and total upper airway obstruction if the subatmospheric airway pressures generated during inspiration are insufficiently opposed by upper airway muscle tone.

In this study the incidence of respiratory disturbances was particularly pronounced in the elderly patients who received morphine infusions. All six patients in the age range 66–75 yr had episodes of hypoxemia, obstructive apnea, and paradoxic breathing (fig. 7). These observations are probably a reflection of the more pronounced effects of anesthesia, surgery, analgesia, and sleep on postoperative hypoxemia,[5] gas exchange,[7] and ventilatory control[37,38] in the elderly patient.

We had anticipated that, because of the site of surgery, diaphragm function would be impaired after cholecystectomy[39] and there would be a predominance of paradoxic breathing in this surgical group. In fact, the incidence of paradoxic breathing in the morphine group was the same in cholecystectomy patients as it was following hip replacement.

Conclusions

The observations reported in this study emphasize the need for continuous respiratory monitoring techniques in the assessment of the respiratory effects of an analgesic drug or technique of analgesic administration.[25] The study has also highlighted the probable synergism between morphine and sleep in the postoperative period.[20] The combination of sleep with analgesia is rarely considered when assessing the respiratory effects of analgesic drugs; this is perhaps surprising since the postoperative patient usually spends a large part of the early postoperative period asleep.

This is particularly pertinent before considering the routine use of new analgesic techniques such as patient-controlled analgesia (PCA). Studies using PCA already have shown that patients controlling their postoperative pain after major intraabdominal surgery may self-administer an infusion of morphine in excess of the rates used in the present study,[40] despite the so-called safeguards built into this type of technique.

Patients in the present study were ASA groups I and II. More seriously ill patients may well show more profound changes in Sa_{O_2}. This suggests that, from the respiratory aspect, regional anesthesia may be a more appropriate form of postoperative pain relief for elderly patients and those "at risk" than continuous opiates.

Alternatively, the careful administration of oxygen may be a safe way of ameliorating the effects of ventilatory irregularities.

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