Anesthesiology
V 41, No 1, July 1974

The Effects of Postoperative Peridural Analgesia on Pulmonary Therapy and Pulmonary Complications

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Effects of continuous postoperative pain relief produced by peridural block with bupivacaine on effectiveness of postoperative pulmonary therapy, incidence of pulmonary complications, and duration of convalescence were evaluated. Patients receiving morphine for postoperative analgesia served as controls. Forty patients scheduled for upper abdominal or hip-fracture operations were studied for 72 hours. They were divided into four equal groups: postoperative peridural analgesia with pulmonary therapy, peridural analgesia without pulmonary therapy, morphine analgesia with pulmonary therapy, and morphine analgesia without pulmonary therapy. Preoperative and postoperative variables compared were: chest x-rays, arterial blood gases, calculated alveolar–arterial P_{O_2} differences ($A\text{-}aD_{O_2}$), vital capacity (VC), peak expiratory flow rate (PEFR), and duration of convalescence. Patients receiving pulmonary therapy combined with either morphine or peridural analgesia postoperatively did not have a decreased incidence of atelectasis, improvement in blood-gas values, or shorter convalescence times compared with control values (no pulmonary therapy). Twelve of 20 patients in the morphine group and seven of 20 patients in the peridural analgesia group showed x-ray evidence of atelectasis 72 hours after operation. Twenty-four hours postoperatively, the morphine group had decreased arterial blood gases (Pa_{O_2}, Pa_{CO_2}), vital capacity, and peak expiratory flow rate, and an increase in $A\text{-}aD_{O_2}$, compared with preoperative levels. Corresponding values in the peridural analgesia group did not reveal a significant improvement over the morphine group. The mean convalescence time of peridural analgesia patients was three days shorter than that of the patients receiving morphine (4.8 ± 0.2 vs. 7.8 ± 0.6, $P < 0.005$). (Key words: Analgesia, postoperative; Anesthetic techniques, peridural; Lung: respiratory complications; Complications, respiratory; Lung: physical therapy.)

ANESTHESIA and the prolonged supine position associated with postoperative convalescence often result in decreased arterial oxygenation.[1-3] Several methods, including voluntary stir-up regime, intermittent positive-pressure breathing, blow bottles, and chest physiotherapy, have been advocated to reverse postoperative hypoxemia. These methods have not been generally effective.[4] Postoperative pulmonary therapy is frequently prescribed to help prevent pulmonary complications.[5-7] However, this therapy may not be effective when the patient's ability to cooperate is compromised by postoperative pain, fatigue, and sedation. Pain has been associated with postoperative restriction of depth of respiration, coughing, sighing, and ambulation.[8,9] Narcotics give partial pain relief, but are accompanied by depression of cough and spontaneous sighing.[10] Peridural nerve block, unlike narcotic analgesia, produces complete analgesia and facilitates better lung expansion without decreasing arterial oxygenation.[11,12]

This study was designed to help answer the following questions: 1) will postoperative pain relief by continuous peridural block improve the effectiveness of postoperative pulmonary therapy; 2) will continuous peridural analgesia, by itself, prevent pulmonary complications; 3) does lack of pain shorten the duration of postoperative convalescence; 4)

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Received from the Department of Anesthesiology and the Anesthesia Research Center, University of Washington School of Medicine, Seattle, Washington 98195. Accepted for publication December 18, 1973. Supported in part by USPHS Grant GM15991-03 from the National Institute of General Medical Sciences, Grant RR-133 from the General Clinical Research Center Program of the Division of Research Resources, National Institutes of Health and a Grant from Sterling-Winthrop Research Institute, Division of Sterling Drug Incorporated, Rensselaer, New York. Presented at the annual meeting of the American Society of Anesthesiologists, Boston, Massachusetts, October 4, 1972.

is the use of a continuous segmental peridural block with bupivacaine (Marcaine) and a roller pump a safe and effective method of relieving postoperative pain?

Procedures and Methods

Forty patients undergoing upper abdominal or hip-fracture operations were studied for 72 hours. They were divided into four groups, each consisting of ten patients who received one of the following postoperative treatments by random selection according to a table of random numbers: 1) peridural analgesia with pulmonary therapy, 2) peridural analgesia without pulmonary therapy, 3) morphine analgesia with pulmonary therapy, and 4) morphine analgesia without pulmonary therapy. Informed consent was obtained from each patient prior to operation. Patients were accepted for study if they were not hypoxemic, had normal chest x-rays, had been ambulatory before their illnesses, and did not have uncontrolled systemic disease. Preoperatively, a Teflon catheter was inserted into a radial artery for blood sampling. All patients received general anesthesia with halothane, 0.5 to 1.5 per cent, nitrous oxide, 60 per cent and oxygen, 40 per cent. *d*-Tubocurarine was used for muscle relaxation. Ventilation was maintained with a Bird Mark IV Anesthesia Ventilator. For the peridural-analgesia patients, following endotracheal intubation, a peridural catheter was inserted at the appropriate vertebral interspace (T10–11 for abdominal operations and L2–3 for hip fracture operations) but not injected with local anesthetic solution. Patients in the morphine group did not receive a peridural catheter. In the recovery room peridural analgesia was initiated by attaching the catheter to tubing from a Holter model 903 pump. This roller pump provided continuous infusion at a rate of 3 to 5 ml/hr from a Volutrol reservoir containing 0.25 to 0.5 per cent bupivacaine solution. The capacity of the reservoir is 150 ml, which provides continuous infusion for 30–50 hours without refilling. The above flow rate produced 6–8-dermatome segmental analgesia localized to the area of surgical incision. Infusion was continuous for 72 hours and was not supplemented by other forms of pain relief. Bupivacaine, 0.5 per cent, was used on the day of operation and then slowly decreased to 0.25 per cent by the third day. Concentrations were altered to allow walking and coughing without discomfort while minimizing the total 24-hour dose. Dermatome level of analgesia was determined by pin-prick evaluation. Lack of significant motor block was determined by measurement of vital capacity (VC) and peak expiratory flow rate (PEFR) (abdominal operations) and by assessing the patient's ability to walk unaided (hip operations). All patients walked as soon and as often as tolerated and were encouraged to breathe deeply and cough each hour during the day. Erect posture was associated with hypotension in most of the patients who had peridural block. This was prevented by prophylactic intramuscular injections of mephentermine (Wyamine) in doses of 60–90 mg at three-hour intervals during the times the patient was walking. Intramuscular injections of morphine were ordered by the attending surgeon for the patients in the morphine groups. They were administered by nurses in doses of 10–15 mg per injection, depending on patient size and age, at intervals calculated to keep the patient comfortable but not obtunded (3 to 6 hr), as is common clinical practice. None of the patients received postoperative antibiotics.

No attempt was made to evaluate directly the magnitude of pain experienced by any individual patient or any group of patients. The following preoperative and postoperative variables were compared: chest x-rays, arterial blood gases, calculated A-aD_{O_2}, vital capacity (VC), peak expiratory flow rate (PEFR), and duration of convalescence. Tests of arterial blood gases, VC, and PEFR were repeated each postoperative day at 10:00 AM. Blood samples were obtained while the patient was breathing room air ($F_{I_{O_2}} = 0.21$). To evaluate the short-term benefit of pulmonary therapy, $P_{a_{O_2}}$ was determined before and 10 minutes after various forms of treatment. Individual treatments evaluated were: 1) chest physiotherapy and postural drainage; 2) balloon inflations; 3) spontaneous positive-end-expiratory-pressure breathing (PEEP); 4) combination of 1, 2, 3; 5) intermittent positive-pressure breathing for 10 minutes (Bennett model TV-2P); 6) ultrasonic nebulizer cough stimulation for 10 minutes (de Villbis model 35) using distilled water mist at 3 ml/min.

Once each day one of the six forms of pulmonary therapy was evaluated on an individual basis by administration of a single treatment to patients in the pulmonary therapy groups.

Long-term pulmonary therapy, consisting of chest physiotherapy, balloon inflations, and spontaneous positive-end-expiratory-pressure breathing (PEEP), was repeated three times each day by the patients in the pulmonary therapy groups. Chest physiotherapy consisted of mechanical percussion of the lateral and lower posterior areas of the chest for 5 to 6 minutes. Balloon inflations were completed by: first, a maximum inhalation held for 5 seconds, then exhalating into a balloon, inflating it to a size similar to that of a balloon containing 3 liters of air. A single-breath balloon inflation was repeated three times per treatment. This maneuver was designed to utilize an inspiratory hold followed by exhalation against the pressure within the balloon.[13,14] Spontaneous PEEP breathing was administered for 10 minutes with a mouthpiece, Hans Rudolph nonrebreathing valve, and spring-loaded Bird PEEP attachment set to a positive end-expiratory pressure of 10 cm H_2O. All pulmonary therapy treatments were administered without added oxygen by Clinical Research Center nurses trained by a pulmonary therapist.

We defined convalescence time as the day of operation subtracted from the day the patient was afebrile, capable of independent ambulation, and did not need parenteral fluids or analgesics. Pulmonary complication was defined as the presence of cough productive of purulent sputum, decreased breath sounds and/or rales, and x-ray evidence of atelectasis or pneumonia. Abnormal x-rays were graded, the number of lobes involved determining the grade (one lobe = grade 1, three lobes = grade 3). Blood samples were obtained daily from patients receiving peridural analgesia to determine the plasma level of bupivacaine. This was done by gas chromatographic assay.[15] Arterial blood-gas analysis was done with an Instrumentation Laboratories 113 Blood Gas Analyzer, with appropriate corrections for body temperature. Alveolar–arterial P_{O_2} difference ($A\text{-}aD_{O_2}$ [mm Hg]) was calculated by: $A\text{-}aD_{O_2} = P_{A_{O_2}} - Pa_{O_2}$ where $P_{A_{O_2}} = (FI_{O_2} \times [BP_{760} - PH_2O]) - Pa_{CO_2}$. A Wright Respirometer was used to measure vital capacity and a Wright Peak Expiratory Flow Meter for peak expiratory flow rate. Significance was determined by Student's t test for paired data and the Fisher exact test for the x-ray data.[16]

Results

Tables 1 and 2 present characteristics of the patients studied. Pulmonary consolidation was found by x-ray 72 hours after operation in seven of the 20 patients receiving peridural analgesia and 12 of the 20 patients receiving morphine. This difference is not statistically significant. Four of the 16 patients who had hip operations and 15 of the 24 patients who had upper abdominal operations also had abnormal 72-hour postoperative chest x-rays, but the difference (25 *vs.* 62 per cent) was not statistically significant. Postoperative fever, purulent sputum, and auscultatory changes in the chest were, in all cases, accompanied by changes in chest x-rays. The patients in the combined peridural groups had a mean convalescence time three days shorter than that of those in the morphine groups (4.8 ± 0.2 *vs.* 7.8 ± 0.6 days, $P < 0.005$).

Tables 3 and 4 show mean arterial blood-gas values and calculated values of $A\text{-}aD_{O_2}$, vital capacity (VC), and peak expiratory flow rate (PEFR) obtained on the day before the surgical procedure and on the first and third postoperative days. Also tabulated are the mean changes in values between the following days: preoperative and first postoperative, first and third postoperative; preoperative and third postoperative. There was a significant difference between Pa_{O_2} values in the peridural hip-operation patients and a similar group who had morphine analgesia (mean change, first to third postoperative day, 13.1 *vs.* 4.9 mm Hg, $P < 0.005$). However, a corresponding improvement in $A\text{-}aD_{O_2}$ was not observed. A significantly different Pa_{O_2} or $A\text{-}aD_{O_2}$ was not found in any other individual or combined group for any of the three periods studied. By the third postoperative day, mean Pa_{O_2} and $A\text{-}aD_{O_2}$ values for all groups had returned to preoperative levels. Postoperative mean Pa_{CO_2} values were decreased from preoperative levels for all

TABLE 1. Age, Height, Weight, Type of Surgery, Sex, Incidence of Postoperative Atelectasis, and Convalescence Time for the Four Individual and Two Combined Groups Studied (Means ± SE)

Treatment Group	Male/ Female	Hip Surgery	Upper Abdominal Surgery	Age (Years)	Height (cm)	Weight (kg)	X-ray Change (No. Pts.)	Hosp. Stay (Days)
Peridural	7/3	5	5	48.2 ±5.6	174.4 ±3.0	76.5 ±5.9	3	4.6 ±0.3
Peridural + respiratory therapy	6/4	2	8	53.4 ±4.0	172.4 ±3.0	75.7 ±3.5	4	4.9 ±0.3
Morphine	6/4	4	6	51.4 ±6.0	169.7 ±2.3	76.1 ±3.4	6	7.7 ±0.7
Morphine + respiratory therapy	4/6	5	5	51.3 ±5.8	170.0 ±1.5	66.6 ±4.2	6	7.8 ±1.0
Peridural	13/7	7	13	50.8 ±3.4	173.5 ±2.1	76.1 ±3.0	7†	4.8* ±0.2
Morphine	10/10	9	11	51.4 ±4.1	169.8 ±1.3	71.4 ±2.9	12	7.8 ±0.6

* Significantly different from combined morphine group, $P < 0.005$.
† Not significantly different from combined morphine group.

TABLE 2. Age, Height, Weight, Sex, Incidence of Postoperative Atelectasis, and Convalescence Time by Type of Surgery and Postoperative Analgesia (Means ± SE)

Treatment Group	Male/ Female	Age (Years)	Height (cm)	Weight (kg)	X-ray Change (No. Pts.)	Hosp. Stay (Days)
Peridural, hips	7/0	58.9 ±3.1	180.7* ±2.2	81.6 ±5.6	1	4.7 ± .3
Peridural, upper abdomen	6/7	46.5 ±4.6	169.5 ±2.5	73.0 ±3.2	6	4.8 ± .3
Morphine, hips	5/4	61.9 ±5.0	171.7 ±1.9	67.2 ±3.5	3	8.9 ±1.0
Morphine, upper abdomen	5/6	42.7 ±4.9	168.2 ±1.8	74.8 ±4.2	9	5.8 ± .6
Combined, upper abdomen	11/13	44.8* ±3.3	168.9* ±1.5	72.6 ±2.6	15	5.7 ± .4
Combined, hips	12/4	60.6 ±3.1	175.5 ±1.8	73.5 ±3.5	4	7.1 ± .8

* Significantly different from combined hip group, $P < 0.01$.

patients regardless of analgesia, type of operation, or postoperative therapy, and this decrease persisted throughout the three days of the study. Patients receiving peridural analgesia had greater decreases in Pa_{CO_2} on the first postoperative day than did morphine patients (−6.2 *vs.* −1.7 mm Hg, $P < 0.01$).

Mean postoperative values of both vital capacity and peak expiratory flow rate were lower in all groups than corresponding preoperative values (except for the peridural-analgesia hip-operation group). This negative change was significantly greater in the combined upper-abdominal-operation group than

TABLE 3. Pa_{O_2}, Pa_{CO_2}, Vital Capacity (VC), Peak Expiratory Flow Rate (PEFR), and Alveolar–Arterial P_{O_2} Difference ($A\text{-}aD_{O_2}$) Values Preoperatively and on the First (D-1) and Third (D-3) Postoperative Days, and Changes (Δ) between Days for the Groups Studied (Means ± SE)

Treatment Group	Pa_{O_2} (mm Hg)			Pa_{CO_2} (mm Hg)			VC (liters)			PEFR (l/min)			$A\text{-}aD_{O_2}$ (mm Hg)		
	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3
Peridural (n = 10)	72.8	70.9	80.7	35.6	29.1	30.1	3.16	2.80	2.82	314	262	296	40.9	45.0	35.2
Δ a, b, c	±4.1	±5.2	±4.3	±1.0	±1.1	±1.5	±.34	±.31	±.30	±48	±32	±30	±4.2	±4.7	±4.0
	[a]−1.9	[b]9.8	[c]7.9	[a]−6.5*	[b]1.0	[c]−5.5*	[a]−.43†	[b]−.03	[c]−.34	[a]−52	[b]35	[c]−17	[a]4.1	[b]−9.8*	[c]−5.7
	±2.9	±3.1	±3.0	± .6	±1.4	±1.3	±.38	±.22	±.37	±31	±12	±30	±4.8	±1.8	±4.6
Morphine (n = 10)	71.3	63.8	71.8	37.0	33.7	33.7	3.10	1.94	2.52	307	201	245	36.7	47.5	39.6
Δ a, b, c	±3.8	±3.1	±2.4	±1.5	±1.4	± .9	±.46	±.18	±.36	±35	±24	±20	±3.8	±2.9	±2.9
	−7.5	7.7*	−1.6	−3.3	.6	−2.4	−1.16	.58	−.58*	−106	44	−62	10.8	−8.2*	4.0
	±5.1	±1.9	±4.6	±1.0	±1.0	±1.0	±.41	±.30	±.16	±39	±29	±28	±4.9	±1.5	±5.0
Peridural + pulmonary	73.1	65.9	78.2	38.2	32.3	32.9	3.34	2.47	3.32	368	265	313	33.7	47.3	33.9
therapy (n = 10)	±2.7	±3.4	±3.2	±1.1	±1.1	±1.5	±.43	±.22	±.36	±30	±28	±33	±3.0	±3.5	±2.5
Δ a, b, c	−7.2*	12.3*	5.1	−5.9*†	.6	−5.3*	−.87	.85	−.02	−103*	48*	−55	13.6*	−13.4*	.2
	±1.6	±2.8	±2.2	±1.4	±1.7	±1.4	±.35	±.29	±.28	±26	±12	±19	±2.5	±3.1	±2.5
Morphine + pulmonary	73.7	68.9	76.9	35.3	35.3	33.0	2.85	2.09	2.26	326	245	273	36.0	40.8	35.1
therapy (n = 10)	±5.2	±2.6	±5.2	±1.7	±1.6	±1.5	±.25	±.18	±.26	±37	±31	±31	±5.3	±3.0	±4.8
Δ a, b, c	−4.8	8.0	3.2	0.0	−2.3	−2.3	−.76	.17	−.59	−81	28	−53	4.8	−5.7	− .9
	±3.4	±3.1	±2.7	±1.4	±1.8	±1.2	±.26	±.09	±.29	±38	±15	±36	±2.9	±2.8	±2.5
Combined peridural	73.0	68.4	79.5	36.9	30.7	31.5	3.25	2.63	3.07	341	263	305	37.3	46.2	34.6
(n = 20)	±2.4	±3.1	±2.6	± .8	± .8	±1.1	±.27	±.19	±.24	±28	±21	±22	±2.7	±2.9	±2.3
Δ a, b, c	−4.6	11.1*	6.5*	−6.2*†	.8	−5.4*	−.66	.43	−.18	−78*	42*	−36	8.9*	−11.6*	−2.8
	±1.7	±2.1	±1.8	± .8	±1.1	± .9	±.26	±.21	±.23	±20	± 8	±18	±2.8	±1.8	±2.6
Combined morphine	72.5	66.4	74.5	36.2	34.5	33.3	2.98	2.02	2.39	317	223	259	36.4	44.2	37.2
(n = 20)	±3.1	±2.0	±2.9	±1.1	±1.0	± .9	±.26	±.12	±.22	±25	±20	±18	±3.2	±2.2	±2.8
Δ a, b, c	−6.2	7.8*	0.9	−1.7	− .9	−2.4*	−.96*	.38	−.59*	−93*	36	−58	7.8	−6.9*	1.4
	±3.0	±1.8	±2.6	± .9	±1.1	± .8	±.24	±.16	±.16	±27	±16	±22	±2.8	±1.6	±2.7

[a] Change between values for preop and D-1.
[b] Change between values for D-1 and D-3.
[c] Change between values for preop and D-3.
* Significant change, $P < 0.01$, for designated time periods within a single group.
† Significant difference, $P < 0.01$, between the values for peridural and morphine groups.

TABLE 4. Pa_{O_2}, Pa_{CO_2}, Vital Capacity (VC), Peak Expiratory Flow Rate (PEFR), and Alveolar–Arterial P_{O_2} Difference ($A\text{-}aD_{O_2}$) Values Preoperatively and on the First (D-1) and Third (D-3) Postoperative Days, and Changes (Δ) between Days for Types of Surgery Studied (Means ± SE)

Treatment Group	Pa_{O_2} (mm Hg)			Pa_{CO_2} (mm Hg)			VC (liters)			PEFR (l/min)			$A\text{-}aD_{O_2}$ (mm Hg)		
	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3	Preop	D-1	D-3
Peridural, hip operation (n = 7)	64.7 ±2.5	59.3 ±0.8	72.4 ±3.5	36.7 ±1.1	31.7 ±1.3	32.7 ±2.3	2.96 ±0.63	2.77 ±.40	3.37 ±.60	234 ±51	241 ±46	262 ±50	43.6 ±2.8	54.7 ±1.4	41.3 ±2.6
Δ a, b, c	[a]−5.4 ±2.9	[b]13.1 ±4.0	[c]7.7 ±3.9	[a]−5.0* ± .9	[b]1.0 ±1.6	[c]−4.0 ±1.5	[a]−.27† ±.66	[b].62 ±.50	[c].41 ±.31	[a]7† ±20	[b]21 ±17	[c]28† ±23	[a]11.1* ±2.7	[b]−13.4* ±2.1	[c]−2.3 ±2.9
Peridural, upper abdominal operation (n = 13)	77.4 ±2.8	73.3 ±4.1	83.2 ±3.2	37.0 ±1.1	30.2 ±1.1	30.8 ±1.2	3.41 ±.25	2.56 ±.21	2.91 ±.18	398 ±22	275 ±21	327 ±19	33.9 ±3.5	41.5 ±3.8	30.9 ±2.9
Δ a, b, c	−4.1 ±2.2	9.9* ±2.4	5.8 ±2.0	−6.8* ±1.0	.69 ±1.44	−6.2* ±1.2	−.85* ±.23	.35 ±.21	−.50 ±.28	−123* ±20	53* ± 8	−71* ±19	7.6 ±4.1	−10.6* ±2.5	−3.0 ±3.8
Morphine, hip operation (n = 9)	68.9 ±5.1	65.2 ±2.3	70.1 ±3.6	33.2 ±1.6	32.0 ±1.4	32.6 ±1.1	2.26 ±.11	2.14 ±.14	2.20 ±.21	246 ±27	233 ±30	248 ±30	42.9 ±5.1	47.8 ±2.2	42.3 ±3.6
Δ a, b, c	−3.7 ±4.7	4.9 ±2.4	1.2 ±4.8	−1.2 ±1.6	.6 ±1.1	− .7 ± .9	−.11† ±.14	.06 ±.10	−.06† ±.18	−13† ±17	15 ±19	2 ±25	4.9 ±4.6	−5.4 ±2.8	−.6 ±4.8
Morphine, upper abdominal operation (n = 11)	75.5 ±3.9	67.3 ±3.3	78.4 ±4.4	38.5 ±1.1	36.5 ±1.3	34.0 ±1.4	3.56 ±.38	1.91 ±.20	2.55 ±.36	375 ±30	215 ±27	268 ±23	31.0 ±3.4	41.2 ±3.3	32.6 ±3.9
Δ a, b, c	−8.2 ±3.9	10.5* ±2.5	0.7 ±3.1	−2.0 ±1.1	−2.3 ±1.8	−3.9* ±1.0	−1.65* ±.29	.64 ±.26	−1.02* ±.16	−159* ±36	53 ±25	−107* ±28	10.2 ±3.6	−8.2* ±1.8	3.2 ±3.1
Combined, hip operation (n = 16)	67.1 ±3.0	62.6 ±1.5	71.1 ±2.5	34.8 ±1.1	31.9 ± .9	32.6 ±1.1	2.56 ±.28	2.39 ±.19	2.71 ±.31	241 ±26	236 ±25	254 ±27	43.2 ±3.0	50.8 ±1.6	41.9 ±2.3
Δ a, b, c	−4.4 ±2.9	8.5* ±2.4	4.1 ±3.1	−2.9 ±1.1	.8 ± .9	−2.1 ±.26	−.17† ±.21	.28 ±.21	.15† ±.17	−4† ±13	18 ±12	13† ±17	7.6 ±2.9	−8.9* ±2.1	−1.3 ±2.9
Combined, upper abdominal operation (n = 24)	76.5 ±2.3	70.5 ±2.7	81.1 ±2.6	37.7 ± .8	33.1 ±1.0	32.2 ± .9	3.48 ±.22	2.26 ±.16	2.74 ±.19	387 ±18	247 ±18	300 ±16	32.6 ±2.4	41.4 ±2.5	31.7 ±2.3
Δ a, b, c	−6.0 ±2.2	10.2* ±1.7	3.6 ±1.8	−4.6* ± .9	− .6 ±1.1	−5.2* ± .8	−1.22* ±.20	.48* ±.17	−.74* ±.17	−140* ±20	53* ±12	−87* ±17	8.8* ±2.7	−9.6* ±1.6	− .3 ±2.6

[a] Change between values for preop and D-1.
[b] Change between values for D-1 and D-3.
[c] Change between values for preop and D-3.
* Significant change, $P < 0.01$, for designated time periods within a single group.
† Significant difference, $P < 0.01$, between the values for hip and upper abdominal operations.

in the combined hip-operation group (ΔVC = −1.22 *vs.* −0.17 liters, first day, −0.74 *vs.* 0.15 liters, third day, $P < 0.01$; Δ PEFR = −140 *vs.* −4 l/min, first day, −87 *vs.* 13 l/min, third day, $P < 0.01$). The decrease in these mean values was not as pronounced in the combined peridural group as in the combined morphine group, but the difference was not statistically significant (ΔVC = −0.66 *vs.* −0.96 liters, first day, −0.18 *vs.* −0.59 liters, third day; Δ PEFR = −78 *vs.* −93 l/min, first day, −36 *vs.* −58 l/min, third day).

Postoperative pulmonary therapy (spontaneous PEEP, balloon inflations, chest physiotherapy, three times each day for three days) with or without peridural analgesia did not decrease the incidence of pulmonary consolidation, improve blood-gas values, or reduce convalescence time, compared with control conditions (tables 1 and 3).

Table 5 shows the short-term effects of individual pulmonary treatments on postoperative Pa_{O_2} (mean Pa_{O_2} values before and 10 minutes after treatment, and change). None of the treatments, either single or combined, provided significant short-term improvement in postoperative Pa_{O_2} with morphine or peridural analgesia.

Correlation between postoperative chest x-ray findings and arterial blood-gas changes was poor (fig. 1). Nineteen of the 40 patients studied showed x-ray evidence of atelectasis or pneumonia in one to three lobes 72 hours after operation. Individual 72-hour postoperative Pa_{O_2} values differed from preoperative values by +20 to −20 mm Hg, independent of postoperative x-ray findings. Of 19 patients in whom atelectasis was visible by x-ray, 11 actually had higher Pa_{O_2} values than when their chest x-rays had been normal.

Excellent segmental peridural analgesia with minimal functional motor impairment was produced by bupivacaine, and was maintained for three days by continuous infusion. Tachyphylaxis was not found with either bupivacaine or mephentermine during the 72-hour period. Plasma levels of bupivacaine of the ten patients studied were (average and range, μg/ml plasma): 0.73 (0.29–0.95) at 24 hours; 1.49 (0.85–2.34) at 48 hours; 1.39 (0.62–2.85) at 72 hours.

Discussion

Patients who had continuous peridural pain relief had more benign postoperative courses, as manifested in earlier interest in reading, earlier walking, and earlier return of appetite, than those receiving morphine. Bromage,[11] in 1955, and Spence *et al.*,[17] in 1971, reported similar observations. This early return to normal activity plus lack of sedation may account for the observed shorter convalescence time of the peridural analgesia patients.

The site of operation (subdiaphragmatic) in the upper-abdominal-operation group may account for the high incidence of abnormal postoperative chest x-rays (62 per cent) found in this group. Others have reported similar findings.[17,18]

The convalescence-time saving of three days for the patients in the combined peridural analgesia group assumes further significance for the hip-fracture patients who received peridural analgesia. They had a saving of 4.2 days compared with hip-operation patients receiving morphine analgesia (4.7 ± 0.3 *vs.* 8.9 ± 1.0 days). Short periods of supine bed rest prior to operation for the patients with hip fractures may account for the lower preoperative Pa_{O_2} values in this group compared with the upper-abdominal-operation group (67.1 *vs.* 76.5 mm Hg, *NS*). However, the postoperative changes in Pa_{O_2} and $A\text{-}aD_{O_2}$ in this group were similar to the corresponding changes in the upper-abdominal-operation patients. The lack of significant improvement in postoperative $A\text{-}aD_{O_2}$ provided by peridural analgesia compared with corresponding changes in the combined morphine group is in agreement with the findings of Muneyuki,[19] but not those of Spence.[17]

Data from this study do not document improvement of the effectiveness of postoperative pulmonary therapy by continuous peridural analgesia. Most pulmonary therapy techniques depend on patient effort and utilize positive-pressure expansion of the lungs.[5,6,7] There is little available information about the relative merits of lung hyperinflations by spontaneous negative pressure (decreasing airway pressure relative to atmospheric during inspiration, as during an unaided breath), compared with the com-

TABLE 5. Arterial Oxygenation ($P_{a_{O_2}}$) before (B), after (A), and Change (Δ) with Various Modes and Combinations of Pulmonary Therapy (Means ± SE)

	$P_{a_{O_2}}$ (mm Hg)				$P_{a_{O_2}}$ (mm Hg)				$P_{a_{O_2}}$ (mm Hg)		
	Before	After	Δ		Before	After	Δ		Before	After	Δ
Peridural + IPPB (n = 9)	79.3 ±4.8	76.7 ±5.4	−2.7 ±2.2	Morphine + IPPB (n = 8)	71.3 ±4.3	71.1 ±3.2	−0.1 ±2.9	Total + IPPB (n = 17)	75.5 ±3.3	74.1 ±3.2	−1.5 ±1.8
Peridural + ultrasonic nebulizer mist inhalation (n = 7)	77.0 ±6.0	74.1 ±6.1	−2.9 ±1.4	Morphine + ultrasonic nebulizer mist inhalation (n = 8)	69.0 ±3.7	68.6 ±3.3	−0.4 ±1.2	Total + ultrasonic nebulizer mist inhalation (n = 15)	72.7 ±3.4	71.2 ±3.3	−1.5 ±0.9
Peridural + PEEP (n = 7)	78.9 ±3.5	79.1 ±3.6	+0.3 ±1.9	Morphine + PEEP (n = 9)	72.7 ±3.8	78.7 ±4.6	+6.0 ±2.3	Total + PEEP (n = 16)	75.4 ±2.7	78.9 ±2.8	+3.5 ±1.6
Peridural + balloons (n = 6)	76.0 ±3.9	71.3 ±3.9	−4.7 ±1.8	Morphine + balloons (n = 8)	75.6 ±5.5	74.5 ±4.6	−4.3 ±1.9	Total + balloons (n = 14)	77.5 ±3.2	73.0 ±3.0	−4.5 ±1.3
Peridural + chest physiotherapy (n = 6)	80.2 ±6.0	80.0 ±5.7	−0.2 ±1.6	Morphine + chest physiotherapy (n = 9)	77.3 ±4.6	73.4 ±3.3	−3.9 ±2.8	Total + chest physiotherapy (n = 15)	78.5 ±3.5	76.1 ±3.0	−2.4 ±1.8
Peridural + combined pulmonary therapy (n = 9)			−1.2† ±1.6	Morphine + combined pulmonary therapy (n = 10)			−1.6 ±1.3	Total + combined pulmonary therapy (n = 19)			−1.4 ±1.0

* Spontaneous PEEP, balloons and chest physiotherapy combined into one treatment.
† Mean Δ for combined pulmonary therapy three times/day for three days/patient.

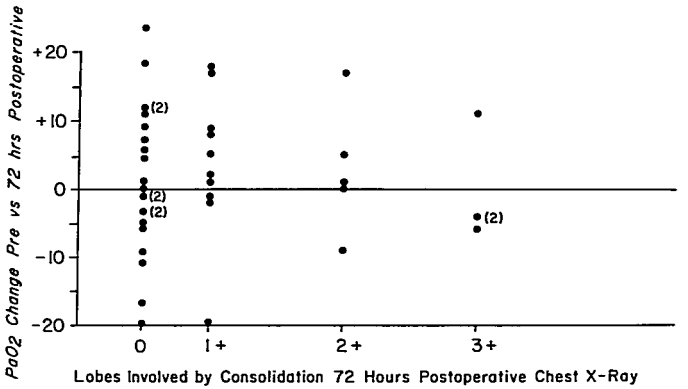

FIG. 1. Individual Pa_{O_2} changes and postoperative chest x-rays.

monly practiced positive-pressure methods (IPPB). Most of our postoperative patients, even though cooperative and without pain, quickly became exhausted by the commonly used techniques. This fatigue seriously compromises a treatment which, to be successful, may depend upon the physical effort exerted by the patient. Effort dependence and positive rather than negative inflation pressures may be factors contributing to the poor results obtained from the pulmonary therapy used in this study. Vital capacity and peak expiratory flow rate measurements are also effort-dependent, which might account, in part, for the postoperative decreases in these values compared with preoperative values. Many peridural analgesia patients who were alert and had good pain relief complained of postoperative fatigue, most often during the first and second days after operation. Therapist technique, interest in the treatment, and encouragement of the patient may also be factors contributing to the success of pulmonary therapy. However, the research nurses involved in this study provided continuous encouragement and supervision of all pulmonary treatments of all the patients in the pulmonary therapy groups, with results which were less than satisfactory.

We were surprised to find alterations in postoperative chest x-rays, sometimes affecting two or three lobes, without associated increases in $A\text{-}aD_{O_2}$ at $F_{I_{O_2}} = 0.21$ (11 of 19 patients with abnormal chest x-rays). The $A\text{-}aD_{O_2}$ is considered a more sensitive indicator of alveolar collapse than chest x-ray changes, as an increase in $A\text{-}aD_{O_2}$ may be found without chest x-ray evidence of consolidation.[18] This change in $A\text{-}aD_{O_2}$ with a normal chest x-ray may be the result of diffuse generalized pulmonary microatelectasis (alveolar collapse) without vascular compensation. The x-ray changes we considered in this study, however, were regional, and may have coexisted with unchanged $A\text{-}aD_{O_2}$ values. Lack of an increase in $A\text{-}aD_{O_2}$ (or decrease in Pa_{O_2}) associated with chest x-ray evidence of alveolar collapse may mean that compensation has occurred by a shift of perfusion away from the collapsed areas to alveoli that are being well ventilated. This may be a mechanism whereby Pa_{O_2} can be stabilized even though rather large areas of lung have collapsed.

The plasma levels of bupivacaine found in this study were of the order found not to be associated with significant subjective or objective effects by Jorfeldt *et al.*,[20] using conscious volunteers. These authors measured maximum arterial plasma levels of bupivacaine of about 2.1 μg/ml following intravenous infusion of the drug (12.5 mg/kg) over 20 minutes. Convulsive plasma levels of bupivacaine are considerably greater than the levels we observed.[21] Therefore the plasma concentrations of bupivacaine measured daily over a three-day period in this study would

indicate a lack of clinically significant systemic accumulation of the drug with long-term peridural infusion.

The need for intermittent reinjections of the blocking agent was completely eliminated by use of the roller pump and large-volume reservoir. The Holter pump provided reliable infusion of the agent at a constant rate. This pump, powered from either wall outlet or battery, allowed the patient to walk without stopping the infusion, and also provided a continuous block with minimal variation in dermatome level. The maximum infusion rate of 6.0 ml/hour of the pump prevents accidental over-infusion of the peridural area by the analgesic agent and undesirable extension of the regional block.

From the data presented in this paper, we conclude that: 1) Pulmonary therapy, with or without complete analgesia, does not provide either short- or long-term benefit to a postoperative patient. 2) Upper-abdominal and hip-fracture operations are associated with 24-hour postoperative decreases in Pa_{O_2}, Pa_{CO_2}, VC, and PEFR, and increases in $A\text{-}aD_{O_2}$ values, compared with preoperative values, and these changes are not significantly alleviated by peridural analgesia compared with morphine. 3) Lack of postoperative pain without morphine sedation allowed early walking, which helped to reduce postoperative convalescence time. 4) The method of providing continuous analgesia by segmental peridural block with bupivacaine and a roller pump was safe and effective.

The authors thank Dr. Thomas F. Hornbein and Dr. Peter M. Winter for review of the manuscript, and Mrs. Glenna Craig for manuscript work.

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