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Clinical Aspects of Continuous Epidural Blockade for Postoperative Pain Relief

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ABSTRACT

Continuous epidural blockade using a 0.4% lidocaine drip during two days was given for the relief of pain in a total of 46 patients of which 41 were otherwise healthy patients who underwent cholecystectomy. A detailed physiological investigation was performed in 23 patients, of whom 13 had blockade of thoracic type with an epidural catheter inserted at the T_5–T_6 interspace and a mean dermatome spread from T_2 to T_{12}. Ten patients had blockade of lumbar type with a catheter inserted at the L_1–L_2 interspace with a mean dermatome spread from T_4 to L_4. The rest of the patients constituted a clinical control group and received the thoracic type of blockade. Successful analgesia was obtained in 92% of the patients with thoracic and in only 10% of the patients with lumbar blockade. Fluids were supplied richly and adequately to the condition of the patients. In a representative period of analgesia about 17 hours after surgery there were in both groups of investigated patients fairly similar changes in physiological variables. On an average there was a significant increase in cardiac output by 43% and in heart rate by 17%, a significant decrease in total peripheral vascular resistance by 27%, a probably significant decrease in mean arterial blood pressure by 9% and no significant increase in heart work. There was a relative improvement of ventilation. The need of lidocaine to obtain analgesia for patients with lumbar blockade was considerably larger, about 50%, compared with patients with thoracic blockade. Clinical signs of toxicity were occasionally seen in all patients with lumbar analgesia but in only three of the patients with thoracic analgesia. Urinary retention requiring bladder catheterization occurred in 6/13 of the investigated patients with thoracic analgesia and in 8/9 of the patients with lumbar analgesia. In this material of high laparotomies, continuous epidural blockade of thoracic type has shown several advantages to blockade of lumbar type concerning some physiological variables but especially concerning the analgesia obtained, the clinical condition and ambulation of the patients.

INTRODUCTION

The technique of anaesthesia during surgery has developed to a high degree of reliability. In the postoperative period, however, the technique of analgesia has not developed to the same degree.

Pain relief is usually provided by some form of central sedation or peripheral nerve blockade. With the former method there is a risk of respiratory and circulatory depression. With the latter method there are disadvantages in the form of discontinuity of the blockade, if injections of analgesic agents are not frequently repeated. The introduction of a continuous epidural analgesia circumvents some of these problems and allows maintenance of a constant analgesic state (9, 14).

From an anatomical standpoint the use of a midthoracic epidural technique for upper abdominal operations appears the best as it can provide a suitable segmental blockade. The anaesthesiologists, however, have been cautious in using this technique because of possible risks of damaging the spinal cord. The clinical advantages of the technique have not been believed to compensate for these risks.

A question is also whether the blockade provokes any circulatory or other functional disturbances. Previous studies have shown high epidural blockade to be associated with a decrease in heart rate, total peripheral resistance, arterial blood pressure and cardiac output (19, 22, 31). On the other hand, one recent study (3), like our own (24) has shown circulation to be well maintained.

In this paper a comparison is made between the midthoracic and lumbar epidural techniques in terms of clinical usage and general trends of physiological reactions.

MATERIAL AND METHODS

The material consisted of 46 patients who received continuous epidural analgesia by constant drip infusion of

Table I. *Investigation programme*

Period I Before epidural blockade		Period II Epidural blockade		Period III Epidural blockade after op.		Period IV Continuous epidural blockade	Period V Without epidural blockade (pain) 60′	Period VI Without epidural blockade (pain) 90′	Period VII Reinstitution of epidural blockade
Circulation	Epidural blockade	+	Operation	+	Postoperative day one	+	+	+	+
Cardiac output		+		+		+	+	+	+
Blood pressure		+		+		+	+	+	+
(art., RA)		+		+		+	+	+	+
(PA, PCV)		+		—		—	—	—	—
Heart rate		+		+		+	+	+	+
Peripheral circulation (skin flow hand and foot)		+		+		+	+	+	+
Temperature (PA, Skin: fore-head, trunk, hand and foot)		+		+		+	+	+	+
Derived values		+		+		+	+	+	+
Respiration		+		+		+	+	+	+
Forced vital capacity		+		+		+	+	+	+
Respiratory muscle force		+		+		+	+	+	+
Respiratory mechanics		+		—		—	—	—	—
Gas exchange (O_2, CO_2)		+		+		+	+	+	+
—		—		$F_{E_{N_2}}$ $F_{E_{N_2O}}$		—	—	—	—
Derived values		+		+		+	+	+	+
Blood		+		+		+	+	+	+
$P_{a_{O_2}}$, $P_{a_{CO_2}}$, $S_{a_{O_2}}$		+		+		+	+	+	+
$C_{a_{O_2}}$, $C_{v_{O_2}}$, pH, Hb, Hct		+		+		+	+	+	+
Lidocaine conc. (venous)		+		+		+	+	+	+
Derived values		+		+		+	+	+	+

0.4% lidocaine into a polyethylene catheter located in the midthoracic or high lumbar epidural space.

In a first group ('investigated group') of 23 patients, investigation of physiological variables were made prior to and after cholecystectomy. Thirteen of these patients were given epidural analgesia of the thoracic type and ten of the lumbar type.

In a second group ('non-investigated group') of 23 patients, all received analgesia of the thoracic type but a closer investigation of physiological variables was not carried out. Of these patients, 19 were cholecystectomized, 2 were treated for thoracic trauma with rib fractures, 1 was operated for hiatus hernia and 1 had renal colic and urethral instrumentation for a stone which subsequently passed.

The mean age for the total group of 42 cholecystectomized patients was 39 years (range 22–68). The mean age for the investigated patients (female 13, male 10) was 37 years (range 22–46) and for the non-investigated patients (female 10, male 9) was 41 years (range 28–68).

The patients in the investigated group were investigated concerning circulatory, respiratory and metabolic variables according to the schedule in Table I. The investigation comprised 7 investigative periods. For the purpose of this report, however, physiological data will be reported only from the preoperative period I and from the postoperative 'steady state' period IV, 24 hours later. In regard to respiration data will also be taken from the 'pain' period VI. The specific methods used for the measurement of the variables will be described in separate papers (24, 25).

Clinical aspects of the epidural blockade will be reported both from the investigated and non-investigated groups of patients. Statistical significance is indicated as follows: $P \leqslant 0.05$*, $P \leqslant 0.01$**, and $P \leqslant 0.001$***.

TECHNIQUE OF EPIDURAL ANALGESIA

The patients were lying on their right side and a catheter (PE 90) to be used for the epidural blockade was threaded through a Tuohy needle at the T_5–T_6 interspace for the thoracic and at the L_1–L_2 interspace for the lumbar type of blockade. A paramedian technique of inserting the needle was used (2). To locate the epidural space in the first 5 cases the hanging drop technique was used (15). In the 41 following cases the loss-of-resistance technique, employing a glass syringe filled with physiological saline, was used. The catheter was firmly fixed onto the back of the patient with adhesive tape.

Preoperatively, for the study in period II, in the thoracic group a bolus injection of 8 ml 2% lidocaine[1] (160 mg) and in the lumbar group 15 ml (300 mg) was given. Postoperatively, during the studies in periods III, IV and VII the blockade was kept continuous with the epidural catheter connected to a standard intravenous-drip set for infusion of 0.4% lidocaine. One patient in the non-investigated group received prilocaine[2] of the same concentration instead of lidocaine.

The drip rate was adjusted by raising or lowering the bottle or by using an infusion pump.[3] Twenty drops of the solution are equal to 1 ml and to 4 μg of lidocaine. The rate of infusion was in the thoracic group begun at 10–15 and in the lumbar group at 15–20 drops per minute. Adjustment of the drip rate was made according to the segmental spread of analgesia until the minimal infusion rate for pain relief was obtained.

The patients with thoracic blockade were nursed in a 30 to 45° sitting up position whereas the patients with lumbar blockade were nursed in a supine position with their heads slightly lowered by 5 to 10°. All physiological measurements were made with the patients in a supine horizontal position.

A way of grading the degree of analgesia was chosen, where any patients who required either supplementary analgesic drugs or a bolus injection of lidocaine (usually about 5 ml of a 2% solution) were rated as having a state of unsatisfactory pain relief. Patients who were pain-free, or who experienced only short episodes of pain that was eliminated in less than 30 min by increasing the drip rate of the lidocaine infusion or by adjusting the body position, were judged to have satisfactory pain relief.

ANAESTHESIA AND SURGERY

No conventional premedication, except 10 mg of diazepam[4] given 6 hours before surgery, was used. The patients retained some effects of the epidural blockade when they arrived at the operation theatre. Anaesthesia was supervised by the authors. It was induced by intravenous injection of 150–300 mg thiopental sodium[5]. Intubation was performed during the muscle relaxation obtained after injection of 50–75 mg succinylcholine[6]. The patients were ventilated manually or in an Engström respirator[7] with 30% oxygen and 70% nitrous oxide. As a rule in the patients of the investigated group, bolus injections of 5–10 ml 2% lidocaine were in addition given to obtain analgesia and muscle relaxation of the abdomen. These injections were in most patients repeated after 30–45 min. If signs of too light anaesthesia appeared, 0.5% halothane[8] in addition was given. In a few cases, during the surgical procedure, bradycardia or nodal rhythm occurred. These changes immediately disappeared after intravenous administration of 0.5 mg atropine. Mean time for anaesthesia was 103 min. When the patients were awakening from anaesthesia the continuous epidural drip infusion with 0.4% lidocaine was begun.

Surgery was performed through an oblique incision below and parallel with the right costal margin. The extrahepatic bile ducts were identified and the cystic duct exposed and opened. Cholangiography was routinely performed. The gallbladder was removed after ligating and cutting off the cystic artery and cystic duct. Mean time for surgery was 84 min.

CLINICAL MANAGEMENT

Fluid therapy. The investigated patients received about 4 litres of fluids during each of the two days of the investigation. Fluid was given intravenously as 5.5% glucose solution with electrolytes. Furthermore, physiological saline with heparin[9] 5 000 IU/l to prevent coagulation in the catheters was given both intravenously and intraarterially through the catheters used for blood pressure measurements and blood sampling. Another amount of fluid was given through the epidural catheter, and on the day after surgery some fluid was taken orally. Two patients required blood transfusion in the evening and night after operation.

Ambulation. An extremely early ambulation of the patients was not attempted, but the ability to sit up in the bed and stand on the floor was tested in the evening after surgery and on the following morning.

RESULTS

The degree of analgesia in the 46 patients varied (Table II). Satisfactory pain relief was noted in 34 patients (74%) and unsatisfactory in 12 patients (26%). In the thoracic group, 33 of 36 patients (92%) had satisfactory analgesia, but in the lumbar group this was the case in only 1 of 10 patients.

The segmental borderlines of analgesia were determined by the use of pin prick test in all periods of the investigation with blockade. In period IV when the infusion had lasted 17 hours the mean dermatome spread of analgesia was T_2–T_{12} for the investigated patients with the thoracic and T_4–L_4 for the patients with the lumbar type of blockade (Fig. 1). The patients of the lumbar group had some degree of motor nerve paralysis of the lower extremities. They were unable to lift the whole leg but able to bend the knee and move the foot.

[1] Xylocaine®, Astra Läkemedel AB, Södertälje, Sweden.
[2] Citanest®, Astra Läkemedel AB, Södertälje, Sweden.
[3] Ivac T.M. 501, Ivac Co. San Diego, California, USA.
[4] Valium®, F. Hoffman-La Roche & Co. AB, Basel, Switzerland.
[5] Pentothal®, Abbot Laboratories, North Chicago, Ill., USA.
[6] Celocurin®, Vitrum AB, Stockholm, Sweden.
[7] LKB Medical AB, Stockholm, Sweden.
[8] Fluothane®, ICI, AB Scanmeda, Göteborg, Sweden.
[9] Heparin, Vitrum AB, Stockholm, Sweden.

Table II. *Estimation of the quality of analgesia obtained after cholecystectomy with continuous epidural blockade*

n = number of patients

	Total group		Thoracic group		Lumbar group	
Analgesia	n	%	n	%	n	%
Satisfactory	34	74	33	92	1	10
Unsatisfactory	12	26	3	8	9	90
Total	46	100	36	100	10	100

Table III. *Duration and dose rate of 0.4 lidocaine drip.*

The amount of lidocaine given as bolus injections is included. n = number of patients. (Mean ± S E M)

Group	n	Hours	Drops/min	mg/h × kg	mg/h × m²
Thoracic	16	38.6	16.2	2.9 ± 0.14	109.5
Investigated	12	40.6	17.4	3.2 ± 0.10	118.1
Non-investigated	4	32.5	12.6	2.1 ± 0.04	83.6
Lumbar					
Investigated	10	35	23.7	4.5 ± 0.33	165.1

The total time and dose of administered lidocaine were exactly known in 26 patients. There were marked differences between those receiving thoracic and lumbar blockades both in infusion rate and in dose expressed in relation to body weight or body surface area. Compared with the investigated patients in the thoracic group the patients in the lumbar group required a 36% larger drip rate, corresponding to a larger dose in mg per hour per kg body weight by 41%, and in mg per hour per square meter body surface area by 40% (Table III).

Samples of venous blood for determination of lidocaine were taken in all investigative periods and at certain other times between the periods. The highest blood concentrations of lidocaine measured during the constant epidural infusion or following bolus injections are shown in Fig. 2. The patients in the lumbar group generally had higher blood concentrations of lidocaine both during the constant infusion and after bolus injections than the patients in the thoracic group. Clinical signs of lidocaine toxicity were frequently seen after bolus injections, especially in the lumbar group.

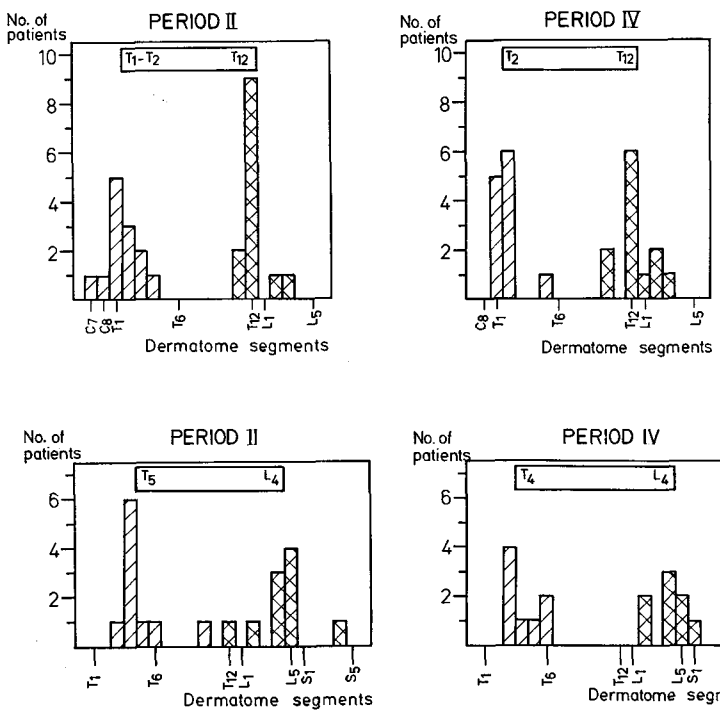

Fig. 1. Upper part. Distribution and average spread of segmental thoracic epidural analgesia in period II (left) and period IV (right). Striped bars indicate the upper level and crossed bars the lower level of analgesia. Horisontal upper bar indicates average spread. *Lower part.* Distribution and average spread of lumbar epidural analgesia in period II (left) and in period IV (right).

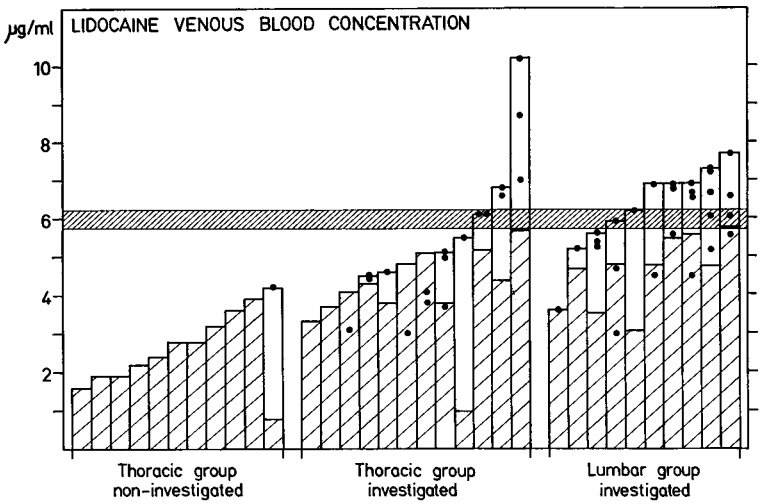

Fig. 2. Lidocaine concentration in venous blood during continuous epidural analgesia in three groups of patients; thoracic group non-investigated, thoracic group investigated and lumbar group investigated. The patients in each group are arranged according to increasing concentration of lidocaine. The striped horisontal bar indicates the concentration in and above which all patients showed clinical signs of toxicity. The striped vertical bars indicate concentration obtained by continuous infusion of 0.4% lidocaine, and the dots maximum concentration after bolus injections of 2% lidocaine.

Comparisons concerning cardiac output ($\dot{Q}$), heart rate (HR), mean arterial blood pressure (MABP), total peripheral vascular resistance (TPR), arterial oxygen tension (Pa_{O_2}) and arterial carbon dioxide tension (Pa_{CO_2}) were made in 18 patients between control period I and the postoperative period IV. These results are presented in Table IV.

Table IV. *Percentage changes of certain circulatory variables from period I to period IV*

Detailed figures are given in Tables 1, 2, 4 and 7 and in Tables 1 and 3 in the respective appendices of two following articles (24 and 25). *n* = number of patients

	Total group investigated		Thoracic group investigated		Lumbar group investigated	
Variable	*n*	Mean	*n*	Mean	*n*	Mean
Cardiac output	18	+43***	11	+43**	7	+43*
Heart rate	18	+17***	11	+12**	7	+24*
Mean arterial blood pressure	18	−9*	11	−10*	7	− 7
Total peripheral resistance	11	−27***	6	−26*	5	−28**
Pa_{O_2}	19	−11***	12	−11***	7	−10**
Pa_{CO_2}	20	− 8***	12	− 6***	8	−10*

Comparisons concerning forced vital capacity (FVC) and forced expiratory volume one second (FEV_{1s}) were made in 16 patients between periods IV and I, and VI and I, respectively. These results are presented in Table V. The values in Tables IV and V in the present report are extracted from the Tables in the appendices of two following papers (24, 25) where all primary and derived values are presented.

All the 42 cholecystectomized patients had gastrointestinal motility about 24 hours after surgery as judged by bowel sounds and flatus, and all were able to take fluid orally on the day after operation.

Ambulation of the patients was possible earlier in the thoracic than in the lumbar group. In the former group most patients could stand and walk in the evening of the day of surgery. In the latter group there was a marked muscle weakness of the legs during the blockade and this was a hindrance to ambulation as was orthostatic hypotension.

The duration of hospital stay is given for 41 of the 42 patients who underwent cholecystectomy. One patient belonging to the non-investigated group is excluded in this context as he had been in hospital during 18 days before operation for

Table V. *Percentage changes in forced vital capacity (FVC) and forced expiratory volume in one second (FVC_{1s}) from period I to period IV and VI*

Detailed figures are given in Table 19 in the appendix of a following article (25). *n* = number of patients

Variable	Total group investigated		Thoracic group investigated		Lumbar group investigated	
	n	Mean	*n*	Mean	*n*	Mean
FVC, per. IV	16	−53***	9	−51***	7	−55***
FVC, per. VI	11	−66***	8	−65***	3	−70*
FEV_{1s}, per. IV	16	−50***	9	−50***	7	−51***
FEV_{1s}, per. VI	11	−68***	8	−66***	3	−74*

treatment of severe chronic bronchitis. The 41 patients represent a homogeneous group without apparent prior complicating disease (Table VI). The patients arrived at the hospital on the day before operation. There was a difference in hospital stay, as the patients in the investigated group stayed 1.9 days longer than those in the non-investigated group. Exploration of the common bile duct was performed in four patients of the former and in only one of the latter group. In the investigated group, the patients with complications stayed 4.7 days longer than those without. There is, however, no noteworthy difference between the non-investigated group and the investigated group without complications in the duration of hospital stay which was about 7 days. In another material from this hospital comprising otherwise healthy cholecystectomized patients with conventional postoperative treatment, the corresponding mean hospital stay was 6.9 days (1).

COMPLICATIONS

A. *Complications arising from analgesic drug and postoperative care*

Toxicity. The patients were considered to have signs of lidocaine toxicity when obvious alterations in behaviour were apparent. We observed but did not note subjective impressions from the patients such as numbness and paresthesia of the face or the extremities. All patients in the lumbar group occasionally showed stronger signs of toxicity such as confusion, aggressive behavior, hallucinations or stupor. In contrast only three of the 36 patients of the thoracic group showed similar signs. No patients had convulsions, but several showed signs of hyperexcitability, exaggerated tendon reflexes and tremor.

Episodes of hypotension or bradycardia were considered to be toxic manifestations unless there were other apparent reasons such as orthostatic hypotension, postoperative haemorrhage or high cranial spread of the blockade. In the lumbar group one patient had a short bout of hypotension with a systolic arterial blood pressure of 60 mmHg associated with a cardiac output of 1.8 l/min. This followed a bolus injection of 8 ml 2% lidocaine (160 mg) superimposed upon the continuous epidural infusion. In the thoracic group one patient had a short period of circulatory depression with a systolic arterial blood pressure of 80 mmHg and a heart rate of 60 beats/min, following a bolus injection of 5 ml 2% lidocaine, also superimposed upon a constant infusion. The hypotension was treated by stopping the epidural drip in both patients, and by additional administration of oxygen to the first patient and by administration of 250 ml of 6% dextran[1] and 0.5 mg atropine intravenously to the other patient.

None of the other patients had circulatory depression in the postoperative period apart from orthostatic reactions seen in the lumbar group. These reactions followed nursing of the patients in different positions and immediately regressed when the patients were placed supine.

Lung complications. X-ray of the lungs was not routinely taken. Complications of the lungs were suspected in eight of the investigated patients (5 with thoracic and 3 with lumbar blockade), as there were moderate fever, productive cough and rhonchi. X-ray of the lungs, however, revealed changes in only two of these patients (1 with thoracic and 1 with lumbar blockade). The first patient had opacities in the lower lobes of both lungs noticed on the fifth postoperative day. These changes regressed following antibiotic treatment. The second patient had an atelectasis in the lower lobe of the left lung noticed on the first postoperative day. This change spontaneously regressed within a few days. Some minor transient atelectases were occasionally observed and are not regarded as noteworthy complications.

[1] Macrodex®, Pharmacia AB, Uppsala, Sweden.

Urinary retention. Record of bladder catheterization for urinary retention was kept in 22 of the investigated patients, 13 of the thoracic group and 9 of the lumbar group. Catheterization of the bladder was required in 16 cases (73%).

In the thoracic group 6 of the patients (46%) required catheterization one or more times. Subsequently all these patients could micturate spontaneously during the blockade.

In the lumbar group 8 of the patients (89%) required intermittent catheterization during the blockade and only one patient in this group could micturate spontaneously under these circumstances.

B. *Complications related to investigation, surgery or technical errors of the epidural blockade*

Investigation. There were 3 complications directly related to the investigative procedures.

One patient, male and aged 46 years, developed a thrombosis in the left radial artery 12 hours after the insertion of a teflon catheter[1] used for pressure recordings and blood sampling. The artery became pulseless and remained so even at a control six months later, but there was at that time no disturbing loss of sensation or function of the hand. In the following patients, the femoral artery was used for this catheterization.

Another patient, male and aged 33 years, developed inguinal haematomas from leakage of blood following the removal of a femoral artery catheter. The haematomas subsequently regressed without any notable sequelae.

A third patient, male and aged 35 years, had urinary incontinence during one week following a single bladder catheterization and thereafter recovered.

Surgery. Notable bleeding postoperatively was found in 2 of the 42 cholecystectomized patients and they required blood transfusion. One of them also was reoperated and a branch of the cystic artery was ligated.

Four patients in the investigated group had choledocholithiasis requiring exploration of the common bile duct. The hospital stay of altogether 9 patients with complications or choledocholithiasis or both (3 cases), was prolonged and was on an average 12 days (Table VI).

[1] Infartkanyl, 1.15 i.d., AB Stille-Werner, Stockholm, Sweden.

Table VI. *Duration of hospital stay*
n = number of patients

Group	n	Mean hospital stay (days)
Investigated	23	8.9
Complication	9	11.8
No complication	14	7.1
Non-investigated	18	7.0

Epidural technique. The first patient in the lumbar group had dural puncture and suffered from cephalalgia for two weeks. This happened when the hanging drop technique was used for the identification of the epidural space (6, 10). After this the loss-of-resistance technique was used, and no dural puncture occurred.

In one patient in the thoracic and one in the lumbar group an epidural vein was punctured and the epidural catheter was threaded into it. The catheter, however, was slowly withdrawn from the vein and placed in another part of the epidural space and could then be used for the epidural infusion without especial signs of toxicity.

Unilateral epidural blockade appeared in two patients (30). We surmise that the tip of the catheter may have been introduced into the anterior epidural space or been pushed out through an intervertebral foramen (21). The catheter was in these cases withdrawn until the tip of it was considered to be situated just inside the epidural space. This manoeuvre resulted in a satisfactory bilateral blockade.

The one patient, who belonged to the non-investigated group, and who received continuous epidural infusion of prilocaine at a total amount of 4 160 mg during 19 hours, showed signs of methaemoglobinaemia (17, 28). He was treated with methylene blue and suffered no sequelae.

DISCUSSION

In the material of patients with epidural blockade there was, using the hanging drop technique for identification of the epidural space, one occasion with dural puncture in a lumbar case. In the cases where the loss-of-resistance technique was used there was no dural puncture. Dawkins & Steel (10) report from their large series of 679

blockades using the hanging drop technique an incidence of dural puncture of 2.6% in lumbar cases and of 1.6% in thoracic cases.

In the patients who received continuous epidural blockade by infusion of 0.4% lidocaine, the thoracic technique showed a clear superiority to the lumbar technique in relieving pain following upper abdominal surgery. Our findings of a satisfactory pain relief of 92% with the thoracic epidural technique after cholecystectomy are in agreement with the report of Green & Dawkins (14) who had a corresponding figure of 83% using the same epidural technique in a similar patient material of upper abdominal laparotomies.

In a few patients there were some difficulties in obtaining a comfortable state postoperatively. These patients complained of diffuse pain despite having analgesia to firm pin prick test in the corresponding dermatomes. This might represent a differentiation of the blockade, the patients continuing to experience some sensory modalities but perceiving them as pain (cf. 5), or might be due to visceral pain unaffected by the epidural blockade. When pain appeared postoperatively, either as a result of unsuitable handling of the patient or as part of the investigation schedule (Table I), the sensation of pain seemed to be exaggerated.

During the two days of continuous epidural blockade there was no obvious sign of tachyphylaxis to lidocaine as the drip rate of the 0.4% solution, sufficient to obtain analgesia, was fairly constant.

The requirement of lidocaine to obtain analgesia with the continuous epidural blockade technique is large and is of the same order of magnitude as the amount used for constant intravenous infusion in the profylaxis of cardiac arrhythmias (Table III) (16). Because of the large amount of drug infused, signs of lidocaine toxicity were carefully watched for. The lumbar technique required a greater dose rate of the drug of 41% in mg per hour per kg body weight compared with the thoracic. The blood concentration of lidocaine was also higher in the patients of the lumbar group, and signs of toxicity were occasionally seen in all these patients (cf. 26).

The risk of provoking toxic signs of the central nervous or the circulatory systems was greatest following bolus injections of 2% lidocaine superimposed upon the constant epidural infusion. The venous blood concentrations of lidocaine are shown in Fig. 2.

An expression for the dose of drug required per segment of analgesia with the two techniques can be given. The mean dose rate per hour per kg body weight (Table III) was divided by the total number of analgesic segments which for the thoracic group were 11 and for the lumbar group 13. The value for the thoracic group of investigated patients was 0.29 mg per segment and for the lumbar group 0.35 mg per segment. In addition to the segments common for both groups the thoracic group contained two high segments (T_2 and T_3), and the lumbar group four low segments (L_1–L_4). To obtain analgesia of the four lumbar segments compared with the two high thoracic segments there was thus a considerably increased requirement of drug, which was probably due to the larger size of the lumbar epidural space and possibly to a greater absorption of drug by the large lumbar nerves.

The influence of the investigation on the drug requirement can be surmised if we compare the drug requirement of a few of the patients with thoracic blockade who were not investigated with those who were investigated (Table III). In the investigated patients there was a 38% higher drip rate and, expressed as amount of drug in mg per hour per kg body weight, the difference was 52% and in mg per hour per square meter 41%. The other 19 patients of the control group also appeared to require a lower dosage than the investigated cases.

The investigation, which lasted two days, also appeared to be tiresome for the patients who therefore tended to complain more than the non-investigated group. A similar comparison for the lumbar patients is not available, as all these patients were investigated. The conclusion drawn from this is that the mean drug requirement for the investigated group is somewhat larger than that required for an ordinary clinical situation.

The changes in circulatory variables in period IV during the continuous epidural blockade were marked. There were in the whole investigated material highly significant increases in HR and $\dot{Q}$ of 17 and 43%, respectively, and an also highly significant decrease in TPR of 27% and a probably significant decrease of MABP of 9% (Table IV).

These results differ from the results obtained during epidural blockade reported by Otton & Wilson (22), McLean et al. (19), and Ward et al. (31), but are in agreement with those of Bonica (3). The effects of major surgery on the circulation has been studied by Colgan & Mahoney (8). They reported a decrease in $\dot{Q}$ of 20% after operation. Many of these patients, however, were seriously ill in contrast to our otherwise healthy patients.

The circulatory changes in the patients in the thoracic and the lumbar groups in all periods of the investigation are presented in detail in a following article (24). Our results indicate that continuous epidural blockade after cholecystectomy has no deleterious effects on the cardiovascular system in otherwise healthy patients kept with adequate blood volume and protected from major toxic effects of the drug.

In connection with upper abdominal surgery there is a reported incidence of atelectasis or pneumonia of 10 to 50% (29). Our number of 8 patients out of 42 (19%) with suspected lung changes does not appear as inordinately great. Using X-ray for the diagnosis only 2 patients had this complication.

The respiratory variables FVC and FEV_{1s} showed highly significant decreases in both period IV and VI compared to period I (Table V). In the whole investigated material there was in period IV, during analgesia, a decrease in both FVC and FEV_{1s} of about 50% and in period VI, in pain, of about 70%. Thus ventilatory function was improved by about 20% during analgesia compared with the pain state in the same patients. In a study by Churchill & McNeil (7) of otherwise healthy cholecystectomized patients where epidural blockade was not used, there was on the first and second day after operation a decrease in vital capacity of about 75%.

The respiration restoration factor (RRF) in our material, calculated according to Bromage (4) but using FVC instead of VC, was about 23%. This is in contrast to the RRF value of 80% reported by Bromage (4), but is in agreement with the work of Finer (11) and Spence & Smith (27). An explanation for this may be that Bromage made his tests on the patients 2 to 4 hours after their awakening from anaesthesia whereas Finer and Spence & Smith and the present authors made tests of the ventilatory function of the patients on the day after surgery. Finer suggests that at this time the patients are greatly influenced by fatigue following epidural blockade probably mostly due to the drug.

The values of Pa_{O_2} and Pa_{CO_2} (Table IV) in our patients on the day after surgery are in close agreement with those reported by Spence & Smith (27). Concerning Pa_{O_2} we found a moderate decrease, although highly significant, of 11% and for Pa_{CO_2} a similar value of 8%. The corresponding values found by Spence & Smith were 13 and 11%, respectively. In another group of their material the use of conventional dosages of morphine caused a more pronounced fall in Pa_{O_2} of 25%. The studies by Spence & Smith (27), Muneyuki et al. (20) and the present authors indicate that continuous epidural analgesia offers the patients a moderate protection from postoperative deterioration of lung function and from hypoxaemia.

The incidence of urinary retention was relatively high. In the thoracic group, 6 out of 13 patients required one or more bladder catheterizations. Eventually all of these were able to micturate during the blockade. In the lumbar group only one out of 9 patients was able to micturate spontaneously. The explanation for the high incidence of bladder catheterizations in the lumbar group appears to be that this technique almost always influences the bladder innervation to a considerable degree, as the mean dermatome spread of analgesia tested by pin prick was T_4–L_4. Although the mean spread with the thoracic technique was T_2–T_{12}, unobserved spread below this level occasionally might have occurred and there is also probably some differentiation between the extent of the blockade of sensory modalities, tested by pin prick, and the sympathetic and parasympathetic blockade (cf. 5). The preganglionic parasympathetic nerves are highly sensitive to local analgesic drugs and the motor nerves to the bladder can easily be blocked (12, 18).

The early return of bowel motility, flatus and ability to tolerate oral fluids suggests that epidural analgesia has a beneficial effect on postoperative gastrointestinal function. Furthermore only 1 of the 42 cholecystectomized patients had nausea in the postoperative period. The use of sympathetic blockade for various gastrointestinal motor disturbances and for improvement of post-

operative bowel function has been suggested (cf. Green, 13).

Early ambulation was possible in the patients of the thoracic group and no notable orthostatic reactions occurred, which was probably due to the lack of blockade in the lower extremities.

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