CONTINUOUS EPIDURAL ANALGESIA— THE USE OF AN INTERMITTENT INJECTION DEVICE*

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THE USE OF continuous epidural analgesia for pain relief after trauma and surgery should have considerable advantages over the use of systemic analgesic agents^{1 2} Segmental anaesthesia readily removes pain and can be particularly useful in the treatment and prevention of respiratory complications following thoracic and abdominal operations^{1 3} Central respiratory depression and psychic depression are avoided and the patient is more relaxed and restful The concomitant sympathetic block can in itself be beneficial in certain disease states, particularly in pancreatitis epidural analgesia has been shown to be a superior method of pain relief^{4 5}

The technique of continuous epidural analgesia has now been generally accepted⁶ To maintain analgesia over periods of many hours or even days, techniques have been described in which the anaesthetic solution has been administered either by intermittent manual injections from a syringe, by intermittent injections of solution from a reservoir, or by continuous infusion^{4 5 7-12} Simpson, Parkhouse, and others¹ gave manual injections at times when extradural analgesia was most beneficial, specifically just prior to physiotherapy treatment Scott and Walker¹¹ have recently described a technique using a unit similar to a standard plastic intravenous giving set with drip chamber and clamp, the injection of local anaesthetic solution being made manually by the use of Martin's blood transfusion pump

Burn¹⁰ describes sterile plastic reservoirs containing local anaesthetic solutions, the dose of which is controlled by intermittently releasing the control clamp for varying lengths of time Massey-Dawkins¹² has used a similar gravity feed chamber and clamp apparatus but controlled his anaesthetic dosage by having the unit run continuously at a selected number of drops per minute

In our own approach to the problem we first used the technique of continuous infusion of the local anaesthetic We tried the gravity feed with drip chamber and later the Harvard continuous infusion pump, filling the syringe with local anaesthetic solution However, with the continuous technique it was more difficult to correlate the rate of infusion with the desired level of analgesia than with the intermittent injection technique With this latter technique, when the effect of the local anaesthetic wore off, the pain was often more severe than that prior to the nerve block On occasion it seemed more difficult to re-establish complete analgesia Irregularities in the timing of such injections were una-

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voidable depending upon the availability of attending personnel. In our hospital nurses are not permitted to give injections of local anaesthetics in any form to rely upon a busy intern staff for properly timed injections was unsatisfactory even though our interns and anaesthetic residents were very helpful and tried their very best to make these injections at the required intervals.

It seemed that if a reliable mechanical device could be evolved to give these injections at the required intervals then the conduct of the anaesthesia would be far more satisfactory. It was decided to modify the Harvard continuous infusion pump in such a way that it could deliver intermittent injections of a constant volume of anaesthetic solution at regular intervals. It is the purpose of this paper to relate our experience with the use of this electrically timed mechanical injecting device on 29 occasions in 26 patients.

DESCRIPTION OF APPARATUS AND ANAESTHETIC TECHNIQUE

The injection apparatus consisted of a modified 900 E infusion withdrawal pump by the Harvard Apparatus Company (Dover Massachusetts). Upon our request the pump was constructed to have only one speed and its motor was controlled by a percentage timer (Fig. 1). This timing device set the pump in

FIGURE 1 End view of apparatus showing percentage timer dial

motion every hour and allowed it to run for a preselected number of minutes. The volume to be injected was calculated as follows. Using a 50 c.c. syringe the pump would deliver 1.27 c.c. per minute. The number of minutes that the pump would run was then set by using the percentage timer. Thus with the timer set at 10 per cent the pump would run for 10 per cent of one hour i.e. six

minutes. In six minutes the pump would deliver six times 1.27 c.c. or approximately 7.6 c.c. The machine then remained dormant for the next 54 minutes before the timer set the pump in motion again.

The time interval of one hour had been chosen arbitrarily on the basis of our experience with continuous epidural analgesia in obstetrics¹³. The only modification we had to make ourselves was to add a weight to the machine in order to keep the syringe in place. This was necessary because the pressure generated tended to disengage the driving mechanism¹⁴ (Fig. 2).

FIGURE 2 Overhead view of apparatus showing placement of syringe loaded with local anaesthetic solution. The cylindrical brass weight seen is necessary to prevent the driving mechanism from disengaging.

The technique of continuous epidural analgesia described by Bromage⁶ was used. The polyvinyl tubing was loosely looped over a sterile swab and then taped along the patient's back. A blunt 24 gauge needle was introduced into the end of the epidural tubing and to gain added length a Baxter R-33 extension was interposed between this and the 50 c.c. syringe which was already filled and placed in the Harvard pump. When it was planned to use the method for postoperative pain relief the epidural was placed preoperatively. All patients were closely observed the majority of them in the recovery room for the first 12-24 hours of the epidural analgesia. Blood pressure and heart rate were recorded at 15 minute intervals and frequent assessment was made of the level of anaesthesia, the degree of relief obtained and the patient's general response to such treatment. This strict routine was later relaxed to allow the patient more rest. Many of our patients were returned to the ward with the infusion pump at their bedside under the supervision of the nursing staff (Fig. 3).

The nurses were instructed to turn off the pump at the first sign of any untoward effect. The empty syringes were replaced by the anaesthetic resident on duty or the intern on call. The attending anaesthetist visited the patient several times

daily to assess the effect of the epidural analgesia and to examine the patient for any possible complications

The longest time that the technique was continued was 7 days and the shortest 12 hours with an average of 3.3 days per patient. Lignocaine (Xylocaine) and

FIGURE 3 The pump at the patient's bedside. In this case the patient was suffering from vascular insufficiency of the left lower limb.

mepivacaine (Carbocaine) were used as the local anaesthetic agents, the least amount of any one injection being 4 ml, the most 9 ml, with an average of 6.2 ml.

A SUMMARY OF OUR CASES (SEE TABLES I, II AND III)

In 15 patients the method was considered satisfactory, that is, the desired level of analgesia was achieved and maintained for the duration that was required without technical difficulties or complications. In 12 patients the results were not completely successful, but we felt that despite the difficulties encountered either in the management of the epidural technique or in the maintenance of the desired level of analgesia, the patients were greatly benefited and we continued with the technique, dealing with the problems as they arose (see below). In 2 patients (19 and 25 in Table I) the result was considered unsatisfactory and the technique was discontinued.

TABLE I
DETAILS OF PATIENTS TREATED IN THIS SERIES

No	Patient	Sex	Age	Diagnosis	Site of epidural	Length of time left <i>in situ</i> (days)	Remarks
1	R H	M	52	Acute exacerbation of chronic pancreatitis	T 11/12	5	Considerable relief despite marked tachyphylaxis Hypotension of mild degree with 2% Xylocaine—no treatment
2	R H	M	52	As above	L 1/2	6	Same patient as above Epidural catheter inserted after 4-day interval Tachyphylaxis re-occurred Laparotomy Satisfactory
3	M K	F	16	Normal labour, man removal of placenta	L 3/4	12 (hours)	
4	J R	F	32	M V A, multiple fractures, ribs affected 3-8 left side	T 12/L 1 T 10/11	2 5	Polyethylene catheter replaced by ureteral catheter after 2 days Very satisfactory Tachyphylaxis by 7th day but treatment completed
5	I V-H	F	53	Ca bladder, cystectomy 1961, hysterectomy for possible spread	L 2/3	3	Very satisfactory
6	R D	M	54	"Cough" fracture—acute exacerbation of asthma	T 12/L 1	3	Very satisfactory with tremendous ability to cough painlessly
7	R S	F	44	Intractable pain right costal margin (?) Metastatic carcinoma	T 9/10	3	Very satisfactory Possibility of morphine withdrawal symptoms
8	A P	M	41	Right femoral artery thrombosis, right sympathectomy	L 3/4	2	Very satisfactory Continuation of operative epidural
9	J M	M	37	Ligation of I V C for multiple emboli	L 1/2	1	Marked tachyphylaxis Sympatholytic effectiveness not assessed
10	K M	M	26	Severe trauma left foot, water-skiing accident	L 1/2	1	Epidural run for sympatholytic effects, Pontocaine added giving effect for 2 hours, so pump worked manually
11	T C	M	76	Ca bladder, cystectomy, and ileal loop	T 12/L 1	5	Continuation of operative anaesthetic Good postoperative course Epidural satisfactory Mild hypotensive effect—no vasopressors
12	J M	M	71	Ca sigmoid colon, external bowel resection	L 1/2	3	Mild hypotension—no vasopressors given but anaesthetic dose reduced Leaking catheter—technical problem
13	R E	M	51	Ca bladder—resection and ileal loop operation	T 10/11	6	Successful but with some tachyphylaxis until last 12 hours when local pain on injection occurred
14	D S	M	40	Bronchiectasis, chronic bronchitis, and emphysema, laparotomy for diverticulitis	L 3/4	4	Very good postoperative course with undoubted facilitation of postoperative breathing

16	N M	I J	35	Abdominal hysterectomy	L 1/2	1	Working well but discontinued because of surgeon's objection
16	A B	M	68	Ileal loop operation for ca prostate	T 12/L 1	3	Continuation of operative anaesthetic Skin analgesia to T 6 but abdominal pain still complained of Hypotension following postoperative dose of Noziran Treated with metaraminol drip
17	O C	M	72	Colostomy for bowel obstruction	T 12/L 1	12 (hours)	Patient a known cardiac No evidence of hypotension Died 20 minutes after being checked by the nurse
18	C A	M	63	Ca pancreas	T 11/12	2	Tachyphylaxis—controlled to some extent by adjusting anaesthetic solutions
19	B M	F	28	Ileal loop operation	L 1/2	2	Marked tachyphylaxis caused unsatisfactory result
20	G D	M	40	Head injury, gastric haemorrhage	L 1/2	4	Demonstrated value of non-narcotic pain relief in head injuries
21	D E	M	50	Vascular insufficiency left leg	L 3/4	4	Clinically effective sympatholytic action which was main purpose of treatment but accompanying pain poorly relieved Sym-pathectomy on 3rd day
22	C A	M	63	Ca pancreas—thrombosis left leg and threatened gangrene	L 2/3 L 4/5	1 4	Same patient as No 18, 5 weeks later Poor results until catheter reinserted, then management satisfactory $\frac{1}{2}$ gr morphine previously for pain relief (Death)
23	R H	F	41	Acute exacerbation of chronic pancreatitis	T 9/10	6	Patient poor witness Management of epidural complicated by intermittent chest pain By 6th day back pain present Catheter removed
24	R B	F	51	Laparotomy—bowel obstruction, adhesions, chronic asthmatic	L 3/4	3	Continuation of operative anaesthetic. Satisfactory pain relief
25	R M	M	47	Arterial insufficiency right leg—sympathectomy	T 12/L 1	12 (hours)	Continuation of operative anaesthetic Unsatisfactory—discontinued
26	M S	F	44	Ca pancreas, liver metastases, intractable pain T 10-12 right side	T 11/12	4	Catheter removed after satisfactory management because of presence of inflammation at site of introduction of catheter See text
27	R H	F	41	Exacerbation of pain, chronic pancreatitis	T 9/10	3	Same patient as No 23, 10 weeks later Again complaining of pain when machine injected, no pain on manual injection, no signs of meningeal irritation
28	H S	M	56	Buerger's disease	L 2/3	6	Initial epidural not successful Hypaque injected X-rays showed catheter veering to the right Reinsertion proved very satisfactory Warm painless leg
29	M S	F	61	Ca lung, pleural and intercostal pain	T 4/5	3	Satisfactory

TABLE II

Type of case	No of cases	Average duration of continuous epidural
Postoperative analgesia	14	2 7 days
Total cystectomy	4	4 days
Vascular	4	2 days
Others	6	2 4 days
Pancreatic pathology	6	4 3 days
Arterial insufficiency lower limbs	3	4 days
Conditions causing pain in ribs and pleura	4	4 days
Normal pregnancy	1	12 hours
Head injury—gastric haemorrhage	1	4 days

TABLE III

SITE OF INTRODUCTION OF EPIDURAL CATHETER

T 4/5	1
T 9/10	3
T 10/11	2
11/12	3
12/L1	6
L 1/2	7
2/3	3
3/4	5
4/5	1

DISCUSSION OF THE PROBLEMS ENCOUNTERED

Tachyphylaxis

This was observed in varying degrees in all our patients. Not only did the duration of action of the local anaesthetic agent become shorter but also the intensity of analgesia obtained from a certain concentration of the drug decreased. Thus larger volumes were often necessary to obtain the same extent of segmental analgesia. Using a mechanical device with injections at fixed time intervals, our most frequent problem was that for the first 12 to 24 hours, sometimes even longer, our patients were comfortable but then began to complain that the pain returned before the next injection occurred. The patients were usually aware of the time of injections and the appearance of severe discomfort 5, 10, and even 25 minutes before the injection was due was discouraging and often demoralizing. The drugs we used were Xylocaine and Carbocaine, and the change from one agent to another gave transient if any improvement in this situation. In almost all our patients the concentration had to be gradually increased from 1 up to 2 per cent, often with added adrenaline.

At present there is no satisfactory explanation for this phenomenon. There is a great deal of individual variation and in some patients the reduction of the effect of local anaesthetic agents is so marked and occurs so rapidly that a continuous epidural analgesia cannot be maintained.

In our experience tachyphylaxis presents the main obstacle in producing a continuous epidural analgesia. We are presently undertaking further studies with

more sophisticated timing devices in order to learn more about the possibilities of overcoming it

Local Irritation and Infection

Three patients complained of localized back pain near the site of ingress of the epidural catheter. The injection aggravated the pain which was subsequently relieved by the local anaesthetic solution. The pain disappeared when the epidural catheter was removed. In two of the patients this discomfort did not occur until the sixth day.

In a third patient signs of meningeal irritation were noted after three days, which disappeared after removal of the catheter. This was the only patient in whom infection was suspected. The patient was a 44-year-old lady suffering from carcinoma of the pancreas with liver metastases. She complained of continuous upper abdominal pain and pain in the lower right chest. For the introduction of the epidural catheter her skin was prepared with an iodine solution that subsequently caused severe dermatitis which became secondarily infected. This was treated with topical application of cortisone and systemic chloramphenicol. By the fourth day of an otherwise satisfactory epidural she had significant neck stiffness and local pain at the site of entry of the epidural catheter. This pain occurred on injection of anaesthetic solution into the epidural space but then subsided for the duration of the local anaesthetic effect. The culture of the tip of the catheter grew coagulase-positive *Staphylococcus aureus*. There were no neurological sequelae and there was some improvement in the patient's pain syndrome.

Maintenance of sterility is difficult with a continuous technique. Changing of syringes, the syringe itself exposed to the air, and the ever possible risk of connections coming apart encourage the development of infection. In our series the catheters were not routinely cultured. However, a recent examination of this problem¹⁵ has produced a rather reassuring result.

Hypotension

Hypotension gave less trouble than expected. Patients with thoracic epidural catheters maintained a satisfactory blood pressure and we were quite content to leave them on the ward with an hourly blood-pressure check, 20 minutes after an injection of epidural solution. Depending on the general condition, the patients were allowed to sit up and we did not notice any untoward effects from this. Blood pressures below 100 mm systolic were observed in four patients.

In three the general status of the patients was such that we decided to institute no treatment but merely to keep the patient under close observation. A fourth patient, after a total cystectomy for carcinoma of the bladder, became severely hypotensive following the injection of a phenothiazine derivative. He was treated with vasopressors and a blood transfusion.

Overdosage

Leaving a mechanical device at the bedside, potentially capable of injecting an overdose into a patient, initially gave us considerable concern even though we

had great confidence that the injection pump, if properly set, would not malfunction. From the strictly mechanical point of view the machine was excellent. The only accident that occurred was due to a human error. An inexperienced resident set the timing device incorrectly so that the pump ran for 90 per cent of one hour instead of for 10 per cent. The setting was promptly obeyed and the patient received a dose of 50 c.c. of 1.5 per cent plain Xylocaine at the rate of 1.27 ml. per minute. Fortunately there were no serious effects from this and the patient expressed his gratitude for two hours of comfort.

Mortality

There were two deaths in this series. One patient, in the terminal state of carcinoma of the pancreas and with an extensive thrombosis in one leg, who had required 30 mg. of morphine every two hours, died after four days of satisfactory epidural analgesia.

The second patient, who was 72 years of age and had known myocardial insufficiency and coronary artery disease, had an emergency operation for a bowel obstruction under epidural anaesthesia. The epidural analgesia was maintained postoperatively and for 12 hours his condition appeared satisfactory and his blood pressure remained stable. He died suddenly a few minutes after being checked by the attending nurse who had found no cause for concern. Death was assumed to be due to myocardial infarction, a request for a post-mortem was refused.

Miscellaneous

Dogliotti and Ciocatto¹⁶ suggested the use of continuous injections of local anaesthetics over a period of three to five days into the epidural space as a means of producing permanent damage to nerve roots, and postulated that this would produce a differential nerve block in chronic pain states. We found no neurological sequelae in our patients, including those who demonstrated signs of local or general meningeal irritation.

A generalized toxic effect from local anaesthetics associated with toxic blood levels with such agents, as reported by Robson and Bromage,¹⁷ was not observed. We believe this to be due to the small volumes of our injections, the largest being 9 ml. of 2 per cent Xylocaine solution.

Our initial concern about injecting solutions containing adrenaline into the epidural space over a long period of time appeared unfounded. It seemed possible that the vasoconstriction caused by the prolonged application of adrenaline could produce tissue damage causing irritation. There was no relationship between the use of solutions with adrenaline and the appearance of signs of meningeal irritation.

CONCLUSION AND SUMMARY

We believe that the results obtained with continuous epidural analgesia maintained with an electrically timed mechanical injection device are encouraging. It is our plan to continue this type of treatment and to investigate the use of more flexible injection devices with a greater sterility factor than the one reported in this presentation. It is felt that the use of such a device contributes towards a

more exact treatment and at the same time frees personnel from the constant pressure of observing a time schedule. The hazard introduced by a device such as this does not, in our opinion, exceed that of repeated manual injections given by a variety of persons. Like any other form of treatment, adequate supervision by nurses and physicians familiar with this technique is essential. With intermittent injections of constant volume and exact timing it has become evident that the main obstacle towards the maintenance of a continuous epidural analgesia is tachyphylaxis. By this we mean a diminished duration of action of the local anaesthetic as well as a diminution of potency. At present there is no satisfactory explanation for this phenomenon.

In all patients it was necessary in the course of treatment to increase the strength of the anaesthetic solution and frequently to add adrenaline to the solutions to obtain a duration of analgesia for one hour using either Xylocaine or Carbocaine. On occasion the duration of action became so short that a continuation of the treatment was not possible. Local irritation caused by the catheter or the local anaesthetic agent was observed in three patients. Symptoms disappeared upon withdrawal of the catheter and there were no after-effects.

Hypotension did not present as great a problem as anticipated. One patient with known coronary artery disease died after twelve hours of continuous epidural analgesia, presumably with coronary infarction.

We have used this device for the injection of intermittent intravenous doses of *d*-tubocurarine in the treatment of tetanus and status epilepticus and believe that its use could be further extended to other agents, such as antibiotics and anticoagulants.

RESUMÉ

L'analgésie épidurale continue pour le soulagement des douleurs post-traumatiques, pour la chirurgie et pour divers états pathologiques devrait avoir un avantage considérable sur les médicaments analgésiques qui agissent sur tout le système. Ceci se rapporte surtout à la prévention des complications pulmonaires.

Dans les travaux sur ce sujet, on a décrit diverses techniques. Ou bien les solutions anesthésiques sont injectées à la seringue de façon intermittente, ou bien ces solutions descendent par gravité, de façon continue ou intermittente.

Dans le présent article, nous faisons part de notre expérience avec une pompe Harvard modifiée destinée à injecter une dose déterminée d'une solution anesthésique locale durant chaque heure. Nous l'avons utilisée 29 fois chez 26 malades.

Les principales indications ont été le soulagement des douleurs postopératoires, les maladies du pancréas, l'insuffisance vasculaire des membres inférieurs et les troubles accompagnés de douleurs pleurales.

En moyenne, le cathéter a été laissé en place 33 jours, et la quantité de solution anesthésique injectée a été de 62 cc par heure.

En utilisant cette technique, on a obtenu un succès complet dans 15 cas, satisfaisant dans 12 cas, et aucun résultat dans deux cas.

La tachyphylaxie s'est avérée le principal obstacle au succès de cette tech-

nique, on a surmonté en partie cet obstacle en augmentant la concentration et le volume des solutions (Xylocaine et Carbocaine) utilisées

L'hypotension ne nous a pas causé les troubles que nous avoins anticipés, cependant, elle peut avoir contribué à l'un des deux décès

Trois malades ont présenté des signes d'irritation locale, et il y eut un cas d'irritation méningée. Ces symptômes ont disparu sans laisser de traces dès l'ablation du cathéter

Les résultats obtenus sont encourageants et ils nous ont apporté beaucoup de renseignements. C'est ainsi que nous utilisons maintenant une pompe plus élaborée et présentant une plus grande sécurité du point de vue aseptie. Nous croyons que la pompe contribue à assurer un traitement plus précis et qu'elle libère le personnel d'une tâche qui fait perdre beaucoup de temps.

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