Time course in thoracic epidural pressure measurement

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The purpose of this study was to measure thoracic epidural pressure at the time of insertion of an epidural needle. The pressure was measured using a closed pressure measurement system after insertion of a Tuohy needle at the T₇₋₈ intervertebral level. This system is unique because it has a pressure transducer equipped with a device which regulates flow through the transducer and prevents the heparinized saline in the system from being evacuated into the epidural space due to sudden pressure change. As reported previously, high negative epidural pressures, up to -60 mmHg, were observed at the moment of epidural puncture. However, the pressure became positive in about 30 sec in 12 of the 13 patients, and stabilized at $+3.7 \pm 3.2$ mmHg (mean $\pm$ SD) within 90 sec. Similar results were observed when the procedure was repeated within a few minutes to the same patients. This suggests that negative epidural pressures at the moment of epidural puncture are artifacts induced by tenting of the dural membrane. Subsequent adaptation of the surrounding tissue results in restoration of the normal positive epidural pressure.

L'objectif de cette étude consiste à mesurer la pression épidurale thoracique au moment de l'insertion d'une aiguille épidurale. Grâce à un système fermé, on mesure la pression épidurale à l'insertion d'une aiguille Tuohy au niveau intervertébral D₇-D₈. Ce système unique contient un transducteur de pression équipé d'un dispositif qui régularise le flux à travers le transducteur et prévient l'évacuation de la solution héparinée dans l'espace épidural lors d'un changement subit de pression. Comme on l'a déjà rapporté, des pressions négatives élevées allant jusqu'à -60 mmHg sont observées au moment de la ponction épidurale. Cependant, la pression redevient positive chez 12 des 13 patients et se stabilise en 90 sec à $+3,7 \pm 3,2$ mmHg (moyenne $\pm$ SD). Des résultats identiques sont observés quand on répète la manoeuvre quelques minutes plus tard chez

les mêmes patients. Ceci suggère que la pression négative produite au moment de la ponction épidurale est un artéfact causé par la dépression de la dure-mère par l'aiguille. L'adaptation subséquente du tissu environnant rétablit la pression épidurale normale.

The loss of resistance technique is the most common method of locating a needle in epidural space.¹ When a Tuohy needle is advanced into the epidural space, the anaesthetist is able to feel the loss of resistance to injection through the needle. One theory to explain this phenomenon is the presence of a negative pressure in the epidural space. However, it is controversial whether the thoracic epidural space exhibits negative pressure. Although some papers^{2,3} concluded that epidural pressure was not always negative, it has been suggested that the epidural pressure may not have been determined accurately because of the influence of liquid flowing into the epidural space. In this study, epidural pressure was measured, after identification of the space by the loss of resistance technique, with a continuous pressure recording system which prevented liquid from flowing into the epidural space.

Negative epidural pressure has been found to be related to the expansion of the epidural space as the needle pushes the dura away from the ligamentum flavum⁴ or by retraction of the ligamentum flavum.⁵ This tenting of the dura is caused by the blunt Tuohy needle.⁶ Dawkins⁷ stated that while the negative epidural pressure was an artifact caused by tenting of the dura by the needle, this would be less likely if the needle were inserted obliquely as in the thoracic region. In this study, epidural pressure was measured continuously following two consecutive punctures of the same ligamentum flavum as described by Zarzur.⁵ The procedure was repeated for each patient with the expectation that epidural pressure at the moment of epidural puncture would vary not only in individual patients, but also if negative measured pressures were artifacts.

Key words

ANAESTHETIC TECHNIQUES: epidural.

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Methods

The study was carried out on 13 adult patients of both sexes undergoing upper abdominal surgery following combined epidural and general anaesthesia. The proce-

FIGURE 1 Epidural pressure recording system.

ture was approved by the local Ethics Committee, was explained to the patients, and their written consents were obtained. The patients received diazepam 10 mg and pentobarbitone 50 mg *po* for premedication 1.5 hr before the epidural puncture. The subject was placed in the lateral flexed position on an operating table. Epidural puncture was performed with a 17 gauge Tuohy needle at the T₇₋₈ intervertebral space using a paramedian approach. After insertion of the needle (with stylet) into a supraspinous ligamentum, the stylet was removed. The needle was then filled with saline and connected to a pressure transducer calibrated from -60 mmHg to +60 mmHg (Baxter disposable transducer: Uniflow system MP5200) via a 60 cm long chloroethylene tube filled with sterile saline. The distal end of the transducer was connected to a reservoir (Figure 1). The transducer is equipped with a device (Intraflow) which regulates flow through the transducer and prevents heparinized saline from being evacuated into epidural space due to sudden pressure changes. When a pressure of 300 mmHg is applied to the reservoir, a continuous flow of 3 ml · hr⁻¹ is delivered through the transducer. However, we confirmed that there was no flow unless the pressure was applied to the reservoir. The zero level was set at the height of spinal process of T₇ prior to measurement. The fluid level in the reservoir was also set at the level of T₇. The epidural space was identified by tactile sensation as the needle passed through the ligamentum flavum and by the sudden deflection of the pressure recorder. The

needle was then held in this position for 90 sec. After recording the epidural pressure, the needle was retracted back through the ligamentum flavum and the recorder reset. The needle was then re-advanced and held in the epidural space for a further 90 sec. The pressure data were recorded using a thermal array recorder (WS-741R, Nihonkoden Co.). The pressures at 30, 60 and 90 sec after epidural puncture were obtained from the recording chart. These epidural pressures were expressed as median values which were calculated from the recording chart, as the minimum pressures plus half of the variation of pressure at 30, 60, 90 sec after epidural puncture. Following completion of the measurements, an epidural catheter was introduced, the patient was turned to the supine position, adequate analgesia to a pinprick assessed 15 min after injection of local anaesthetics, and general anaesthesia was induced. Both Friedman and Wilcoxon T tests (non-parametric statistical analysis) were used to analyze differences in pressures at 30, 60 and 90 sec following epidural puncture. The Wilcoxon T test was used to compare differences in epidural pressure at 90 sec between the first and second epidural punctures in each patient. *P* values <0.05 were considered significant.

Results

Thirteen patients were studied (ten men and three women, aged 57.9 ± 8.8 yr (mean ± SD)). The typical variation in epidural pressure is illustrated in Figure 2. The

FIGURE 2 The typical variation in epidural pressure. Y axis is epidural pressure recorded as mmHg. X axis shows time course of epidural pressure wave at a recording speed of 50 mm per minute (5 graduations per one half minute). Respiratory and cardiac oscillations are easily seen.

TABLE I Pressure recordings after first puncture

Patient	Greatest negative pressure (mmHg)	Epidural pressure (mmHg)					
		30 seconds after epidural puncture		60 seconds after epidural puncture		90 seconds after epidural puncture	
		median	± swing	median	± swing	median	± swing
1	-19	7.0	1.0	5.5	1.5	5.5	1.5
2	<-60	3.0	1.0	2.0	2.0	3.0	2.0
3	-8	-1.0	1.0	-1.0	1.0	0.5	1.5
4	-10	5.0	1.0	5.0	1.0	5.0	1.0
5	<-60	-14.0	1.0	2.5	0.5	10.5	1.5
6	-9	7.0	1.0	7.0	1.0	8.0	2.0
7	-5	2.0	1.0	2.0	1.0	3.0	1.0
8	-7	-1.5	2.5	-2.0	3.0	0	3.0
9	0	5.0	2.0	4.5	2.5	4.0	3.0
10	0	2.0	2.0	1.5	1.5	1.5	1.5
11	4	7.5	1.5	8.0	1.0	5.0	2.0
12	<-60	-2.5	1.5	-2.0	2.0	-2.0	2.0
13	-14	3.0	2.0	3.5	2.5	4.0	2.0
mean		1.7		2.8		3.7	
SD		5.5		3.1		3.2	

pressure-time measurements by patient are shown in Tables I and II.

High positive pressures from +30 mmHg up to +60 mmHg were observed during passage of the needle through the ligamentum flavum. Following epidural puncture, high negative pressures ranged from <-60 mmHg to +4 mmHg in the first puncture, from <-60 mmHg to +2 mmHg in the second puncture were observed for 3-4 sec in almost all patients. However, the epidural pressure soon equilibrated to a positive value in 12 of the 13 patients and stabilized at $+3.7 \pm 3.2$ mmHg within 90 sec in both expiratory and inspiratory phases in these patients. These extremes of pressure varied greatly both between subjects, and between the first and the second punctures. No differences in epidural pressure

were determined at 60 sec and 90 sec following epidural puncture. Pressure-time profiles were similar for the first and second epidural punctures. No differences in epidural pressure were determined between the first and second punctures 90 sec after puncture.

When the subjects exhibiting negative epidural pressure 30 sec following puncture were separated from the others in order to examine the influence of age, the mean age of the four patients (patients No's 3, 5, 8, 12) exhibiting negative epidural pressure 30 sec following puncture was 48.5 ± 6.7 yr (mean $\pm$ SD) and for the others was 61.1 ± 8.2 yr (mean $\pm$ SD).

Discussion

While an initial negative pressure was observed a few

TABLE II Pressure recordings after second puncture.

Patient	Greatest negative pressure (mmHg)	Epidural pressure (mmHg)					
		30 seconds after epidural puncture		60 seconds after epidural puncture		90 seconds after epidural puncture	
		median	± swing	median	± swing	median	± swing
1	<-60	-1.0	1.0	2.5	1.5	5.5	1.5
2	-12	-1.0	1.0	1.0	1.0	3.0	2.0
3	-38	-2.5	1.5	2.0	2.0	2.5	1.5
4	-8	5.0	1.0	5.0	1.0	5.0	1.0
5	-38	-7.0	1.0	9.5	0.5	10.0	2.0
6	1	7.5	1.5	7.5	1.5	7.5	2.5
7	-2	4.0	1.0	6.0	1.0	4.0	2.0
8	-3	-1.5	1.5	0.5	1.5	0.5	3.5
9	-2	4.0	2.0	4.0	2.0	3.5	2.5
10	0	1.0	1.0	1.0	1.0	1.0	1.0
11	2	4.5	2.5	4.5	1.5	3.5	2.5
12	-25	-2.5	1.5	-3.5	1.5	-3.0	2.0
13	0	3.5	1.5	4.0	2.0	4.0	2.0
mean		1.1		3.4		3.6	
SD		3.9		3.2		3.1	

seconds following puncture, the epidural pressure quickly equilibrated to a positive value in 12 of the 13 patients. No variation in this pressure was observed between the first and second punctures in the same patient. These observations suggest that the initial negative pressure was not indicative of the true epidural pressure. Rather it is likely to result from an artificial mechanism, such as tenting of the dura by the blunt Tuohy needle, with subsequent adaptation of the surrounding tissue to stabilize the pressure.

Paul⁸ investigated the influence of the pressure generated by low lumbar epidural injection of bupivacaine upon epidural pressure and showed that the epidural pressure stabilized within 60 sec, irrespective of the pressure applied by the local anaesthetic injection. In this study, pressure measurements were conducted at 30, 60 and 90 sec after epidural puncture and these reproducibility was confirmed by repeating the experimental procedure.

The loss of resistance phenomenon often occurs upon placing the needle in the epidural space, or in another pseudo-epidural space within adipose or loose connective tissues. Correct placement of the needle in the epidural space was confirmed in all 13 patients by the presence of respiratory oscillations and by adequate analgesia following injection of local anaesthetic.

Telford² reported that spontaneous respiration with its associated negative intrapleural pressure would be insufficient to cause negative lumbar epidural pressure. In this study, using a closed measurement system, as in Telford's report, positive pressures were also observed in the tho-

racic epidural space. This method facilitates the measurement of pressure gradient changes because of the inability of epidural space pressure to equilibrate with atmospheric pressure. A closed measurement system originated with Brook's indicator,⁹ and was recommended by Dawkins¹⁰ as a means of observing negative epidural pressure. However, this indicator does not accurately reflect epidural pressure because the air and liquid from the needle are evacuated into the epidural space and thus themselves may affect the epidural pressure.¹¹ The transducer used in this study was equipped with a device which prevented the liquid in the system from being evacuated into the epidural space should a negative pressure suddenly occur.

Usubiaga¹² reported that the magnitude of the epidural pressure change to positive or the rate of change in pressure produced by jugular compression was dependent on the position of the head. When the patient's neck was flexed, a rapid and large increase in epidural pressure occurred. In this study, patients were positioned in the lateral recumbent flexed position, and their necks were flexed. Therefore, the results may have been influenced by this positioning.¹³

Moreover, since negative pressures can be lower in older patients in relation to Usubiaga's paper,¹⁴ it was expected that the age would influence epidural pressure. It is interesting that the ages of the four patients that exhibited negative epidural pressures at 30 sec following puncture were less than in those patients that exhibited positive epidural pressures at 30 sec.

It is uncertain why only one patient exhibited negative pressure for more than 30 sec following epidural puncture, but it is possible that the patient's tissue adaptability was impaired following puncture.

In conclusion, thoracic epidural pressure was measured continuously using a closed pressure measurement system after placing a needle in the epidural space using a loss of resistance technique. The negative pressures found at the moment of epidural puncture are probably artifacts and the subsequent equilibration to positive pressures was due to adaptation of the surrounding tissue.

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