Acta Anaesthesiol Scand 2008; **52**: 256–261

ACTA ANAESTHESIOLOGICA SCANDINAVICA
doi: 10.1111/j.1399-6576.2007.01506.x

Epidural puncture can be confirmed by the Queckenstedt-test procedure in patients with cervical spinal canal stenosis

T. Yokoyama[1], T. Ushida[2], F. Yamasaki[3], S. Inoue[2] and K. A. Sluka[4]
[1]*Department of Anesthesiology and Critical Care Medicine,* [2]*Department of Orthopedics,* [3]*Department of Clinical Laboratory, Kochi Medical School, Nankoku, Japan and* [4]*Physical Therapy and Rehabilitation Science Graduate Program, University of Iowa, Iowa City, IA*

Background: The loss-of-resistance test is the most popular method for identifying the epidural space, but it cannot confirm epidural puncture. Therefore, we developed a new method to confirm epidural puncture by assessing indirect changes in epidural pressure using the Queckenstedt-test procedure, which increases subarachnoid pressure by compressing the internal jugular veins. Because this new method depends on the dynamics of cerebrospinal fluid, blockade of cerebrospinal fluid flow, as with severe spinal stenosis, is predicted to reduce changes in epidural pressure. Thus, in this study, we examined the effect of spinal stenosis on the Queckenstedt-test procedure.
Methods: Epidural puncture using the loss-of-resistance test was utilized to insert an electrode in patients undergoing cervical spine surgery. Epidural pressure was monitored during bilateral compression of the internal jugular veins to confirm epidural puncture. The insertion of the electrode into the epidural space was confirmed by observation of muscle twitch evoked by electric stimulation.
Results: In 60 patients, epidural puncture was performed with the loss-of-resistance test; a second trial was required in 13 patients. Increased epidural pressure was observed in 57/73 trials. When increased epidural pressure was observed, epidural puncture was always successful. The sensitivity and specificity of this method was 92.0% and 100%, respectively. The positive and negative predictive values were 100% and 66.7%, respectively.
Conclusion: An increase in epidural pressure during bilateral compression of the internal jugular veins could offer a reliable method for confirming epidural puncture in combination with the loss-of-resistance test, even if patients have potential spinal canal narrowing.

Accepted for publication 28 August 2007

Key words: Epidural puncture; confirmation; monitoring; epidural pressure; Queckenstedt-test.

© 2007 The Authors
Journal compilation © 2007 The Acta Anaesthesiologica Scandinavica Foundation

The use of epidural anesthesia was first developed by Sicard (1) and Cathelin (2) in 1901 and the loss-of-resistance test was first described by Sicard and Forestier (3) in 1921. The first insertion of an epidural catheter was performed by Curbelo (4) in 1947. The catheter must be located in the epidural space for effective continuous epidural anesthesia. At present, the loss-of-resistance test is the most widely used method for identifying the epidural space. Although the loss-of-resistance test recognizes a sudden decrease in resistance, it cannot confirm epidural puncture and it can be difficult to identify the epidural space with this test, in obese or elderly patients. Many devices and methods have been contrived to objectively detect the changes in the epidural pressure (5–7), but there is no method to confirm epidural puncture by intentionally changing the epidural pressure.

We developed a new method to confirm epidural puncture by indirect changes in epidural pressure using the modified Queckenstedt-test procedure (8). The Queckenstedt-test is a test for evaluation of cerebrospinal fluid flow disturbance. The principle of this method is to increase the subarachnoid pressure by compressing the internal jugular vein (9). The epidural space and subarachnoid space are separated only by the dura mater and thus epidural pressure also increases by compressing the internal jugular vein. Iwama and Ohmori (10) documented that Queckenstedt-test increases epidural pressure during continuous epidural infusion. We applied this procedure for confirming epidural puncture. This new method for confirming epidural puncture depends on the dynamics of cerebrospinal fluid flow (Fig. 1). The increase in epidural pressure is observed within 1 s after the compression of the jugular vein, but blockade of cerebrospinal fluid flow may reduce the response of the epidural pressure change (9). This method, theoretically, results in no false positives. However, we hypothesize that narrowing the spinal subarachnoid space above the puncture will reduce the increase in epidural pressure during bilateral compression of the internal jugular veins and result in a false negative. If the increase of epidural pressure is not detectable in patients with a narrowed spinal canal, this new method cannot be used for patients with potential spinal canal stenosis. Therefore, the present study was conducted to examine the effect of spinal canal stenosis on the reliability of this new method.

Methods

This study was approved by the Ethics Committee of Kochi Medical School. Informed consent form was given to all subjects. The epidural pressure monitoring combined with the Queckenstedt-test procedure was examined in 60 patients, ASA physical status I–II, with cervical spinal canal stenosis and complaints of neurological symptoms. All subjects were being seen for their first cervical spine surgery. The severity of cervical canal stenosis was evaluated by at least 10 pre-operative transverse cervical MRI slices 5 mm in thickness. Severe and massive cervical cord compression (flattening ratio $>50\%$) with the complete absence of cerebrospinal fluid space in both the axial and sagittal MRI views was defined as 'a massive block' in this study.

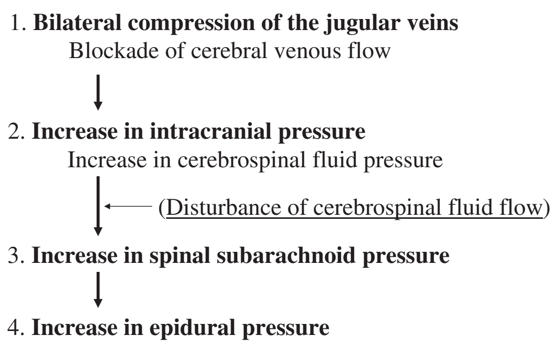

Fig. 1. The principle of the Queckenstedt-test procedure. Increase in intracranial pressure caused by bilateral compression of the jugular veins is transmitted to the epidural space, but disturbance of cerebrospinal fluid flow may reduce the change of epidural pressure.

On the day before surgery, in the ward, compression of the bilateral internal jugular veins for 10 s caused no symptoms in the 60 patients used in this study. On the operation day, epidural puncture was performed with the patient in the left lateral position using the loss-of-resistance test to identify the epidural space between T10 and L5. Epidural puncture was performed after induction of anesthesia and endotracheal intubation without muscle relaxant (sevoflurane 7% combined with fentanyl 2 μg/kg). A 17-gauge Tuohy needle (BD PerisafeTM Epidural Catheter Kit, Becton Dickinson, Franklin Lakes, NJ) was inserted and advanced until loss-of-resistance to saline was obtained, and neither cerebrospinal fluid nor blood was aspirated. Epidural pressure monitoring was started by a three-way stopcock connected to a Tuohy needle and an extension tube filled with normal saline (Fig. 2a). The pressure was monitored using a pressure transducer (DTX PlusTM DT-XX, Becton Dickinson). The transducer was calibrated at the level of the spine with the patient in the left lateral position. Changes in epidural pressure were displayed on a monitor with a scale of 0–20 mmHg at a speed of 2.5 cm/s and recorded during bilateral compression of the internal jugular veins for up to 5 s (Fig. 2b). An increase in the epidural pressure during bilateral compression of jugular veins indicated a successful epidural puncture (Figs. 1 and 2c,d). This method is different from the Queckenstedt test in a point of monitoring epidural pressure and assessing a successful epidural puncture. Therefore, we call this method the epidural Queckenstedt test (E-QST). After epidural pressure monitoring, an epidural catheter electrode, for diagnosing spinal conduction block, was introduced through the Tuohy needle and advanced 5–7 cm cephalad. The insertion of the bipolar platinum electrode (Unique Medical Co., Tokyo, Japan) into the epidural space was confirmed by observation of para-vertebral or leg muscle twitch evoked after electric stimulation (5–15 mA, 2 Hz) (Neuropack, Nihonkoden, Tokyo, Japan). Failure of epidural puncture was defined when the electrode did not advance when or no muscle twitch was observed. When the electrode advanced <5 cm, another epidural puncture was attempted at another level. The electrode was used for an electrical conduction test to diagnose spinal stenosis during surgery to determine the surgical spinal decompression area; thus the electrode

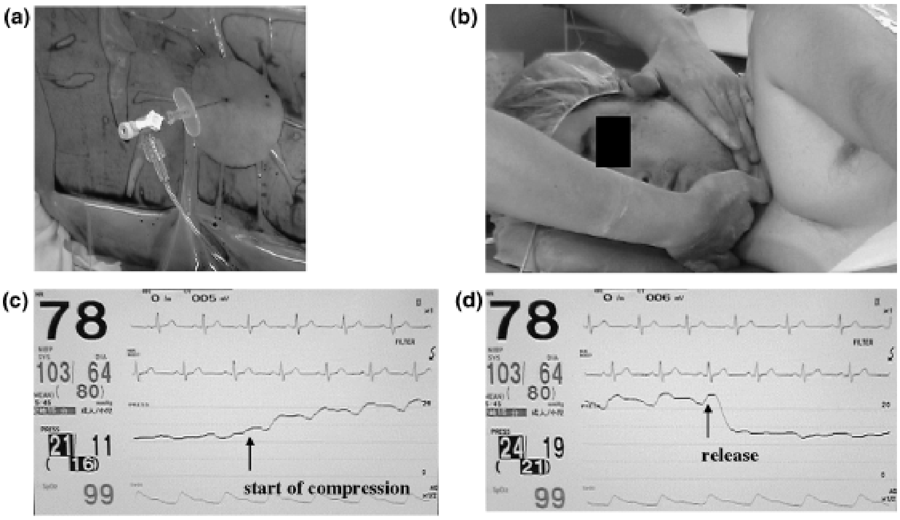

Fig. 2. Illustration of the method for confirming epidural puncture by increases in epidural pressure during bilateral compression of the jugular veins and monitoring of epidural pressure. Epidural pressure was monitored through a three-way stopcock connected to a Tuohy needle and an extension tube filled with normal saline (a). The jugular veins were compressed for 5 s (b). The epidural pressure clearly increased from 11 to 21 mmHg after the start of the bilateral jugular veins compression (c). The epidural pressure quickly returned to the previous level after the release of the compression (d).

should be located below the portion of spinal canal stenosis (11). The electrode was removed after surgery and the location of the electrode confirmed by postoperative radiography.

Epidural pressure was recorded before and after compression of the bilateral internal jugular veins. Values are shown as mean ± SD. A positive E-QST was defined as a clear and reproducible increase in epidural pressure more than 1 mmHg during compression of the bilateral internal jugular veins. A positive electric stimulation was defined when a clear para-vertebral or leg muscle twitch evoked after electric stimulation was observed, confirming a successful epidural puncture. χ^2 test with Yates' correction for 2×2 tables was used to compare the categorized data of E-QST and epidural puncture. A P value of 0.05 or less was considered to be statistical significant. In addition, sensitivity, specificity, positive and negative predictive values of E-QST were calculated with standard formulas.

Results

Thirty-three male and 27 female subjects were enrolled in the current study. Age, height and weight were 67 ± 13 years old (range: 29–90 years old), 157 ± 11 cm (range: 141–180 cm) and 58 ± 14 kg (range: 32–88 kg), respectively. All patients complained of paresis, paraesthesia and/or neuropathic pain, and underwent cervical spinal surgery; 26 cases of cervical laminoplasty, 24 cases of anterior decompression and fusion, six cases of enlargement of the intervertebral foramen, three cases of spinal tumor resection and one case of atlas–axis fixation. In all 60 cases, no symptoms appeared during bilateral compression of the jugular veins in the ward on the day before surgery. In all patients, apparent cervical spinal cord compression was observed by pre-operative MRI. In 47 patients, the flattening rate of the spinal cord was $>50\%$. In four of these patients, there was a complete absence of cerebrospinal fluid space in both the axial and sagittal MRI views; these were diagnosed as 'a massive block.'

Increased epidural pressure during bilateral compression of the jugular veins was clearly observed in 45 patients on the first attempt of epidural puncture with a Tuohy needle using the loss-of-resistance test. Muscle twitch normally triggered by electric stimulation through the epidural catheter electrode was observed (duration: 100 ms, intensity: 20 mA, 2 Hz) (Table 1). In three patients, however, the electrode did not advance more than 5 cm and a second trial was required for the electrode to advance more than 5 cm. On the second trial, increased epidural pressure during bilateral compression of the jugular veins was observed similar to the first epidural puncture.

In the remaining 15 patients, increased epidural pressure during bilateral compression of the

Table 1

Summary of the results.

First trial				Second trial			
No. of patients	E-QST	Electrode advance	EST	No. of patients	E-QST	Electrode advance	EST
42/60	Positive	>5 cm	Positive				
3/60	Positive	<3 cm	Positive	3/3	Positive	>5 cm	Positive
5/60	Negative	>5 cm	Positive				
10/60	Negative	no advance	–	10/10	Positive	>5 cm	Positive

Thirteen second trials were required when the catheter advanced <5 cm. E-QST; increase in epidural pressure by the Queckenstedt test procedure. Electrode advance; length of advancement of the catheter inserted into the epidural space.
EST; electric stimulation

jugular veins was not observed on the first epidural puncture trial despite the fact that the loss-of-resistance test was normal. In 10/15 patients the electrode did not advance. In these 10 patients we concluded that the epidural puncture had failed. During a second epidural puncture trial that was required in these 10 patients there was an increased epidural pressure during bilateral compression of the jugular veins, the electrode advanced greater than 5 cm and electric stimulation was positive. The epidural pressure waveform on the second trial was clearly different from the first trial. In the other five patients, however, the electrode advanced >5 cm and there was a muscle twitch triggered by electric stimulation. Post-operative radiography showed that the electrode was located in the epidural space. In these five patients, therefore, we concluded that the epidural puncture was successful although there was a negative E-QST.

A total of 73 trials (60 first trials and 13 second trials) were performed, and increased epidural pressure was observed in 58 trials with a positive electric stimulation. The baseline epidural pressure of those 58 trials was 7.2 ± 4.0 mmHg (range: 0–17 mmHg) and increased by 5.6 ± 3.2 mmHg (range: 2–12 mmHg) during E-QST. The lowest increase in epidural pressure was 2 mmHg but clearly detectable.

In 15/73 trials, there was no increase in the epidural pressure coincident with a positive loss-of-resistance test. In 10 of the 15 trials the epidural puncture was judged as an unsuccessful epidural puncture and there was also a negative E-QST. In other five trials, however, epidural puncture was confirmed by electric stimulation in spite of negative E-QST. Out of these five patients, four patients had severe and massive cervical cord compression and were regarded as 'a massive block' because no cerebrospinal fluid space was observed in both the axial and the sagittal MRI views. Three of these 'massive block' cases were males older than 80 years. The other was a 68-year-old female with a spinal tumor. The remaining one case without 'massive block' was an 84-year-old male with severe ossification of the posterior longitudinal ligament. Finally it was confirmed in all patients by post-operative radiography that the electrode was located in the epidural space, and there was no complication with the E-QST method.

Table 2

Categorized data of E-QST and epidural puncture.

Epidural puncture	Success	Failure
Positive E-QST (No.)	58	5
Negative E-QST (No.)	0	10

Positive E-QST; increase in epidural pressure by the Queckenstedt-test procedure.
E-QST, epidural Queckenstedt-test.

As shown in Table 2, when the E-QST was positive there was no case of a failed epidural puncture. A negative E-QST with a failed epidural puncture was observed in 10 patients. A negative E-QST with a positive electric stimulation was found in five patients ($\chi^2 = 39.4$, 1 df, $P < 0.0001$). These data allowed for calculations of the sensitivity, specificity, positive predictive value, and negative predictive value. The sensitivity and specificity of this method were 92.0% (58/63) and 100% (10/10), respectively. The positive predictive value and negative predictive value was 100% (58/58) and 66.7% (10/15), respectively. No complications with the E-QST method were observed in this study.

Discussion

The loss-of-resistance test subjectively recognizes epidural puncture by feel when the needle pierces the ligamentum flavum to reach the epidural space. However, if the tip of the Tuohy needle reaches some space other than the epidural space, such as the thoracic cavity after passage through the ligament, the resistance disappears, and thus epidural puncture cannot be absolutely confirmed by the loss-of-resistance test in this instance. Therefore, we developed a brief method to confirm epidural puncture objectively (8).

There are several prior reports of methods to confirm epidural puncture objectively. For instance, Ghia et al. (12) confirmed the location of epidural catheters using the epidural pressure waveform. In this method, however, there is the possibility of a false positive because the epidural space and the thoracic cavity cannot be distinguished by monitoring changes in epidural pressure with rhythmic pulsation. However, theoretically, the E-QST method should not result in a false positive. The epidural nerve stimulation test by Tsui et al. (13) is attractive because it can be performed within a few minutes before and after insertion of the catheter (14); however, this test needs a stimulation apparatus, an insulated Tuohy needle and an ECG adaptor. Usually, the operating room does not include these pieces of equipment. On the other hand, the E-QST requires only a three-way stopcock, an extension tube and a pressure transducer, and can be performed within a couple of minutes. The pressure transducer can be shared for arterial pressure monitoring. Even when the loss-of-resistance feeling is unclear, epidural puncture can be confirmed conveniently and repetitively with E-QST. Therefore, we can avoid catheterization into an inappropriate space and overadvancement of Tuohy needle that might lead to dural puncture.

The current study describes a new method to monitor epidural pressure combined with E-QST that depends on the dynamics of cerebrospinal fluid flow. Queckenstedt described a method to evaluate cerebrospinal fluid flow disturbance (9). Compression of the internal jugular vein increases intracranial pressure and consequently increases subarachnoid pressure. This procedure, therefore, increases epidural pressure and can be used reliably to confirm epidural puncture without a false positive. Of course, the new method cannot be used for patients with complete cerebrospinal fluid flow disturbance.

In the current study, therefore, reliability of E-QST was examined in orthopedic patients undergoing cervical decompression surgery because those patients usually have severe spinal canal stenosis and undergo electrical diagnosis of conduction block level intraoperatively (11). In addition, the epidural puncture was confirmed by electric stimulation to be the same as the epidural nerve stimulation test when the electrode was inserted at lower thoracic or lumbar areas. There is a potential risk of bradycardia and plaque dislocation of the carotid arteries during bilateral compression of the jugular veins. However, bilateral compression of the internal jugular veins for 10 s caused no symptoms on the day before surgery in 60 patients. Furthermore, no patients had complications with the E-QST method in this study.

In the current study, an increase in epidural pressure was not observed in five patients as expected in patients with complete cerebrospinal fluid flow disturbance. In fact, four of them had complete massive block of the subarachnoid space, and the remaining one patient had severe ossification of the posterior longitudinal ligament, possibly with the complete absence of cerebrospinal fluid space. In the other 55 patients, the electrode was inserted successfully into the epidural space after observation of an increase of epidural pressure during bilateral compression of the internal jugular veins. Hence, narrowing of the spinal subarachnoid space above the puncture does not reduce the reliability of the E-QST method except in patients with massive block. These results indicate that the E-QST method can be applied more reliably for common patients. Usually, when we confirm the epidural insertion of the catheter under local anesthetics, it requires, at shortest, 10 min and patient co-operation. Using the E-QST, however, we can confirm epidural puncture in a few minutes before insertion of the catheter objectively.

In summary, we evaluated the effect of cerebrospinal fluid flow on the reliability of a new method to confirm epidural puncture measuring changes in epidural pressure during bilateral compression of the internal jugular veins. This E-QST method was examined in patients complaining of paresis, paraesthesia and/or neuropathic pain due to spinal canal narrowing. No complications with the E-QST were manifested. Furthermore, in cases with successful epidural puncture, epidural pressure increased during bilateral compression of the internal jugular veins except in five cases with massive block or severe ossification of the posterior longitudinal ligament. Therefore, the E-QST method, epidural pressure monitoring combined with bilateral compression of the internal jugular veins, offers a safe and reliable method to confirm epidural puncture, even if patients have some potential cerebrospinal fluid flow disturbance.

References

1. Sicard A. Extradural injection of medication by way of the sacroccygeal canal. *C R Soc Biol (Paris)* 1901; **53**: 396.
2. Cathelin F. A new route of spinal injection; A method of epidural injections by way of the sacral canal; application to man. *C R Soc Biol (Paris)* 1901; **53**: 452.
3. Sicard JA, Forestier J. Radiographic method of exploration of the external spaceusing Lipodol. *Rev Neurol* 1921; **28**: 1264.
4. Curbelo MM. Continuous peridural segmental anesthesia by means of a ureteral catheter. *Anesth Analg* 1949; **28**: 1–13.
5. Shal JL. Identification of the epidural space. *Br J Hosp Med* 1991; **46**: 60–2.
6. Lechner TJM, van Wijk MGF, Maas AJJ. Clinical results with a new acoustic device to identify the epidural space. *Anaesthesia* 2002; **57**: 768–72.
7. Saito K, Inomata S, Uemura A et al. Training of epidural anesthesia with pressure-guided method in pediatric patients. *Masui* 2002; **51**: 927–30.
8. Yokoyama T, Yamashita K, Manabe M. Confirmation of epidural puncture using Queckenstedt test procedure. *J Clin Anesth (Jpn)* 2005; **29**: 1815–8.
9. Queckenstedt H. Zur Diagnose der Rückenmarkskompression. *Deutsche Zeitschrift für Nervenheilkunde* 1916; **55**: 325–33.
10. Iwama H, Ohmori S. Continuous monitoring of lower thoracic epidural pressure. *J Crit Care* 2000; **15**: 60–3.
11. Tani T, Ushida T, Yamamoto H et al. Waveform changes due to conduction block and their underlying mechanism in spinal somatosensory evoked potential. Technical note: a computer simulation. *J Neurosurg* 1997; **86**: 303–10.
12. Ghia JN, Arora SK, Castillo M et al. Confirmation of location of epidural catheters by EP waveform and computed tomography cathetergram. *Reg Anesth Pain Med* 2001; **26**: 337–41.
13. Tsui BC, Guenther C, Emery D et al. Determining epidural catheter location using nerve stimulation with radiological confirmation. *Reg Anesth Pain Med* 2000; **25**: 306–9.
14. de Medicis E, Tetrault JP, Martin R et al. A prospective comparative study of two indirect methods for confirming the localization of an epidural catheter for postoperative analgesia. *Anesth Analg* 2005; **101**: 1830–3.

Address:
T. Yokoyama
Department of Anesthesiology and Critical Care Medicine
Kochi Medical School
Kohasu, Oko, Nankoku 783-8505
Japan
e-mail: yokoyamt@kochi-u.ac.jp