

# A test to prevent subarachnoid and intravascular injections during epidural analgesia

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Not one of the present tests for the correct position of an epidural catheter can reliably detect intravascular, intrathecal and extra-epidural placement.

A simple rapid test has therefore been developed. Following placement of the epidural catheter an initial aspiration test for cerebrospinal fluid and blood is performed. Air (1 ml) and then saline (2 ml) are injected through the epidural filter.

The test involves 3 steps after removal of the filter: (i) the open end of the epidural catheter is lifted and the liquid meniscus present in the catheter is observed to drop rapidly; (ii) the open end of the epidural catheter is lowered and the liquid meniscus is again observed to fill the catheter with clear liquid and no blood; (iii) the presence of air in the catheter during backflow confirms the correct position in the epidural space relative to a position in the subarachnoid space.

The combined steps were prospectively examined in 278 cases of surgery under epidural analgesia. The test reliably detected 5 cases of intravascular and 2 cases of subarachnoid placement. No cases of local anaesthetic toxicity or undiagnosed subarachnoid injection were noted. Not one of the 6 failures to establish epidural analgesia could be attributed to intravascular or intrathecal placement. The sensitivity, specificity and positive predictive value for correct epidural placement of the catheter were found to be 95,5%, 63,6% and 98,5% respectively. The time required to perform the test was less than 30 seconds in 92% of the cases.

The test provides an additional easy rapid method of avoiding the two main dangerous misplacements of an epidural catheter, but requires further investigation to determine sensitivity and specificity more accurately.

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The verification of correctly placed epidural catheters is of great importance, since intravascular or subarachnoid injection of local anaesthetic agents may be fatal. Since

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1933 various tests have been developed<sup>1,2</sup> and introduced in anaesthetic practice to eliminate the potentially grave complications.<sup>3</sup> No single test has yet been described which can reliably detect intravascular as well as intrathecal placement of the epidural cannula.<sup>4-7</sup>

We have developed a simple set of manoeuvres involving the free inflow and outflow of liquid, with the latter containing bubbles of previously injected air. The test is mainly designed to exclude both the dangerous misplacements, i.e. subarachnoid and intravenous placement, and also indicate placement in the epidural space. These manoeuvres are used routinely in our clinical practice and we report the results of a prospective study done over a 1-year period.

## Patients and methods

All patients scheduled for surgery over a 1-year period and who requested or agreed to epidural analgesia were included in the trial. Although we use the test routinely in pregnant women, patients requiring epidural analgesia for labour were not included in the study because we would not have been able to exclude intravascular placements as the doses of local anaesthesia used for pain relief in labour are usually too low to cause signs of toxicity on intravascular injection.

Standard preparation of the patients for epidural analgesia included overnight fasting, benzodiazepine premedication, intravenous preloading with a crystalloid and monitoring of blood pressure, electrocardiography and pulsatile oximetry.

The epidural cannula was placed with the patient in the lateral position at a spinal level appropriate for the planned operative procedure (T10 - L5).

A 16- or 17-gauge reusable Huber type Tuohy needle (Dyna Medical Inc.) was used with a midline approach and the epidural space was identified on loss of resistance to saline in a glass syringe. A 17 g or 18 g epidural catheter (Preferred; Medical Products) was threaded 15 cm through the Tuohy needle. The Tuohy needle was removed and the epidural catheter withdrawn until 3 - 4 cm remained in the epidural space.

A 3 ml glass syringe was connected to the epidural catheter and gently aspirated to detect obvious backflow of blood or cerebrospinal fluid (CSF). If blood was seen in the epidural catheter, the catheter was pulled back 1 - 2 cm until no further blood could be aspirated. The catheter was repeatedly flushed with saline and aspirated until no more obvious blood could be seen.

### The test

A 0,22 micron millipore filter (Millex-GS) was connected to the epidural catheter and 1 ml of air and 2 ml of saline were injected sequentially through the catheter.

#### Step 1 — rapid inflow

The filter was disconnected and the end of the epidural cannula lifted at least 30 cm above the level of insertion into the back. The meniscus was observed in the cannula. A rapid fall of the meniscus (greater than approximately 1 cm per second) was considered a successful or positive free inflow test.

#### Step 2 — rapid outflow, no blood

With the filter still disconnected, the end of the epidural catheter was lowered at least 30 cm below the level of insertion. The meniscus was observed. A rapid filling of the epidural catheter (more than approximately 1 cm per second) with no blood backflow was considered a successful or positive outflow test. When no outflow was obtained, the 3 ml syringe was connected to the epidural cannula and gentle suction applied — this backflow of the meniscus was also considered successful.

#### Step 3 — bubble outflow

The last part of the test entailed the observation of air bubbles in the epidural cannula near the patient's back. A spontaneous end to the backflow was considered a confirmatory sign of epidural versus subarachnoid placement but this was not an essential part of step 3. Bubbles flowing out spontaneously or gentle suction to obtain the air bubbles near the point of penetration into the patient were both considered successful or positive.

The start of the period required for the test was taken as the slow injection of the 1 ml of air and the end of the period of the test as the injection of the first dose of the local anaesthetic agent. The duration of the test was noted to be either less than 30 seconds, 31 - 60 seconds or more than 60 seconds.

A dose of 5 - 10 ml of 0,5% bupivacaine or 2% carbonated xylocaine was slowly injected and the patient observed for 3 - 5 minutes for hypotension and possible loss of sensation and movement.

After 3 - 5 minutes the remaining dose of local anaesthetic was carefully and slowly injected and the patient monitored for signs of intravascular or intrathecal injection of local anaesthetic agent by the anaesthetist's talking to the patient continuously, inquiring about symptoms of toxicity and checking for very rapid onset of motor paralysis. The height of the block was determined by loss of temperature sensation to ethylchloride spray.

A successful epidural block was defined as: (i) lack of excessively high block or low blood pressure (excluding subarachnoid placement); (ii) lack of symptoms indicating toxicity (excluding intravascular block); (iii) adequate analgesia for surgery to be performed, indicating correct epidural placement.

Attempts were made to determine the cause of any unsuccessful blocks. Special attention was paid to the diagnosis of intravascular injection or paravertebral placement as causes of unsuccessful blocks. The presence of analgesia over the majority of segments below the umbilicus was considered evidence against such incorrect placement.

The sensitivity, specificity and positive predictive value of the test were calculated. Ethical institutional approval for the study was obtained.

## Results

There were 278 (38 male and 240 female) consecutive epidural patients in the study over a 1-year period. The average age ( $\pm$  standard deviation) of the patients was 39,78 ( $\pm$  17,82) years with a range from 16 to 90 years.

The outcome of the 3 steps of the test are shown in Table I. There was only 1 patient where step 1 (rapid inflow) was negative and there were no patients where all 3 steps were negative. The various combinations of positive and negative tests related to the outcome of the epidural block are shown in Table I. Not one of these 278 patients showed systemic signs of local anaesthetic toxicity and a successful epidural block was established in 270 cases.

Table I. Outcome of surgery following various combinations of tests

Step 1	Step 2	Step 3	Total	Unsuccessful
neg	pos	pos	—	—
neg	neg	pos	1	0
neg	neg	neg	—	—
pos	neg	pos	16	0
pos	neg	neg	7	1*
pos	pos	neg	12	2†
pos	pos	pos	242	5‡
			278	8

\*Pos = positive test (i.e. safe to inject); 'neg' = a negative test (i.e. unsafe to inject or failure to obtain a positive result). †Unsuccessful = patients who did not have surgery solely under epidural anaesthesia.

\* Partial block; false positive.

† Both subarachnoid punctures.

‡ Includes a patient with a missed segment, a patient requesting a general anaesthetic (successful epidural) and three false-positive results.

After initial placement of the epidural catheter, there were 5 cases where blood flowed back freely; all 5 patients had successful epidurals after resiting of the catheter as described above. There were no cases where blood was demonstrated with gentle aspiration.

During step 3 of the test, gentle aspiration on the catheter to obtain backflow and demonstrate air bubbles in the backflow was required in 134 (46.7%) cases. There were 2 cases of subarachnoid puncture which were both diagnosed on failure to see air bubbles and continuation of backflow (negative step 3). A confirmatory test was done by aspiration of fluid and testing for dextrose on a paper test strip.

The extra time taken to perform the test was less than 30 seconds in 257 cases, 31 - 60 seconds in 15 cases and longer than 60 seconds in 6 cases. There were no failures due to undiagnosed intravascular or subarachnoid injection of local anaesthetic. Of the 8 patients who did not have their surgery under epidural anaesthesia, 2 patients had dural punctures where the anaesthetic was converted to a spinal technique and 6 patients had failed epidurals: 1 patient had a missed segment; 1 patient had a successful epidural but requested a general anaesthetic after the start of surgery and there were 4 patients where the full 3-step test indicated correct placement but interligamentous placement was presumed given a failure to establish an epidural block. These last 4 patients were deemed to be false positive for placement of the catheter in the epidural space.

The sensitivity, specificity and positive predictive value of the test for detecting intravascular placement were 97.4%, 100% and 100% respectively; for detecting subarachnoid placement 93.1%, 100% and 100%; and for correct epidural placement as opposed to any misplacement (e.g. subarachnoid, interligamentous) 95.5%, 63.6% and 98.5% respectively (see Appendix for calculations).

## Discussion

The ideal test should differentiate between correct and incorrect placement of an epidural catheter wherever the misplacement may be. Such a test has not yet been described. As a second best option, the test should consistently diagnose the two main dangerous misplacements, viz. intravascular and subarachnoid.

Although facilities for immediate and aggressive resuscitation of a patient should prevent total spinal anaesthesia from causing death, efforts should still be made to prevent total spinal anaesthesia from occurring. An intravascular injection of local anaesthetic solutions such as bupivacaine or etidocaine may be cardiotoxic<sup>2</sup> and may lead to fatalities even with appropriate therapy. These two complications should therefore be detected and prevented by any proposed test.

Three methods to detect misplacements and avoid the dangers of incorrect injection of local anaesthetic agents are advocated at present: (i) careful aspiration of the catheter for blood or CSF;<sup>3</sup> (ii) injection of a pharmacological test dose; e.g. 15 µg epinephrine;<sup>2,3</sup> (iii) fractionation of the local anaesthetic dose.<sup>3</sup>

Careful aspiration by itself is insufficient. Energetic suction can cause an epidural vein to collapse over the catheter, which results in a false-negative test.<sup>5</sup>

The value of 15 µg epinephrine as a test dose of intravenous injection has been questioned by Crawford<sup>4</sup> and Scott<sup>5</sup> and defended by Moore.<sup>6</sup> The clinical usefulness of reliance on such a subtle and possibly unsafe test was questioned by Leighton *et al.*,<sup>5</sup> who stated that the proportion of false-negative results of intravenous test doses was 50%, and by Cartwright *et al.*<sup>7</sup> who found a 12% rate of false-positive results.

Fractional and slow injection of the local anaesthetic dose is always advisable as the epidural catheter may go astray in unusual places, e.g. the subdural space.<sup>8</sup>

Although aspects of the test (as described in 'Methods') have been published before,<sup>10-12</sup> a complete detailed description of this combined 3-step test is not available; neither has a large prospective study been published to our knowledge. Our study also evaluated the test over a wide range of ages and operative procedures.

The 3 steps of the test positively indicate, firstly, placement of the catheter in a hollow space (step 1), secondly, enough backflow to rule out collapse of a vein over the catheter opening (step 2), and thirdly, placement outside the subarachnoid space as the return of air bubbles indicates placement outside the subarachnoid space (step 3).

There are two advantages to the test. Firstly, it was found to exclude accurately the dangerous and potentially lethal misplacements of the epidural catheter in the subarachnoid and intravascular spaces. Secondly, when all steps are positive, one is more confident that the local analgesic agent will establish an epidural block given sufficient time, and less tempted to change to a general anaesthetic agent or reintroduce the epidural catheter, especially in the elderly where onset may be delayed. False-negative individual steps of the test do not detract from the usefulness and advantages of the test as all steps should be considered together. It is therefore not suggested that negative individual steps be used to indicate removal of the catheter

but rather that positive steps be used to strengthen one's confidence of correct placement.

The possibility of subdural injection of at least some of the local anaesthetic destined for epidural placement should always be kept in mind, especially with the use of multihole catheters; slow and fractionated doses are always advisable.

## Conclusion

This test provides an easy, rapid method of avoiding two of the main dangerous misplacements of epidural catheters. Because of the small number of incorrect placements, further studies are indicated to determine more accurately the false-positive and false-negative rates of this test with intravascular, intrathecal and other incorrect placements.

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## Appendix. Sensitivity and specificity

The sensitivity of a test is an expression of how well the test identifies occurrences of a given event in a population.

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{True positives and false negatives}}$$

The specificity of a test is an expression of how well the test identifies only occurrences of the event of interest.

$$\text{Specificity} = \frac{\text{True negatives}}{\text{True negatives and false positives}}$$

The positive predictive value is an expression of how well the test performs as a test.

$$\text{Positive predictive value} = \frac{\text{True positives}}{\text{True positives and false positives}}$$

The sensitivity and specificity of the test (all steps combined) were calculated for each of the main points of interest: intravascular placement, subarachnoid placement and correct

placement in the epidural space relative to placement anywhere outside the epidural space (interligamentous, intravascular, etc.). Positive is defined as 'safe to inject' and negative as unsafe to inject or a failure to obtain a positive answer.

### Intravascular placement

The test as a whole indicated that 266 patients were safe to inject, i.e. not an intravascular placement as there were no patients with signs of toxicity. There were no false positives.

The specificity of the test is calculated from negative outcomes where a negative outcome is either blood in the cannula (5 cases detected — true negatives) or failure of the test in step 2 to obtain backflow: there were 7 such cases (i.e. false negatives).

True positive	266
False positive	0
True negative	5
False negative	7
Sensitivity	97,4%
Specificity	100%
Positive predictive value	100%

### Subarachnoid placement

The test indicated 'safe to inject' (not in the subarachnoid space) in 257 patients. As there were no total spinal anaesthetics, there were no false-positive tests. The test detected both the subarachnoid placements (true negatives) and there were 19 cases with failure to obtain backflow (also defined as a negative test) where a successful epidural block was established (i.e. not in the subarachnoid space). These were considered to be false negative (i.e. test indicated unsafe to inject, but was actually safe).

True positive	257
False positive	0
True negative	2
False negative	19
Sensitivity	93,1%
Specificity	100%
Positive predictive value	100%

### Correct epidural placement

For this analysis, a positive test is defined as at least 1 of the 3 steps indicating correct placement and 1 of the positive steps should be a return of air bubbles (i.e. positive step 3). There were thus 259 cases of a positive test of which 4 were false positive (i.e. failure to obtain epidural analgesia).

There were 19 negative tests (i.e. indicating placement not in the epidural space) of which 12 were false-negative tests (i.e. not indicating placement in the epidural space but actually placed correctly in the epidural space).

True positive	255
False positive	4
True negative	7
False negative	12

Positive is defined as indicative of correct placement in the epidural space. Negative is defined as indicative of placement outside the epidural space, i.e. extraneous to the spinal cord and coverings, e.g. interligamentous, muscle.

Sensitivity	95,5%
Specificity	63,6%
Positive predictive value	98,5%