Electrophysiological stimulation (Tsui test) is feasible for epidural catheter positioning in adults with chronic back pain: a cohort study

La stimulation électrophysiologique (test de Tsui) est faisable pour le positionnement d'un cathéter péridural chez l'adulte souffrant de maux de dos chroniques: une étude de cohorte

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Abstract

Purpose Determining epidural catheter placement and accurately depositing corticosteroids at the site of the pathology in adults with chronic back pain can be challenging. Fluoroscopy is considered the standard of care for guiding epidural catheter positioning and subsequent injection in patients receiving epidural corticosteroids, but the technique has some limitations. We hypothesized that electrophysiological stimulation using the Tsui test is feasible for determining the appropriate epidural catheter position in adults with chronic back pain receiving epidural corticosteroids.

Methods We conducted a prospective cohort study of 12 patients receiving epidural corticosteroid injections for chronic back pain. Anatomical landmarks and epidural needle positions were initially confirmed by fluoroscopy. Epidural catheter position was assessed according to

sensory and motor responses, as described by Tsui et al. (Can J Anaesth 45: 640–644, 1998). The current was increased slowly from zero until muscle activity was visible or the current reached 10 mA. The catheter was then advanced until muscle responses occurred in the desired myotome. The test was deemed positive or negative according to the Tsui criteria. The anatomical level was confirmed by fluoroscopy prior to injection.

Results Electrophysiological stimulation effectively established the appropriate epidural catheter position in 11 patients (92%). Epidural stimulation occurred at a mean (SD) threshold of 3.95 (3.35) mA. The kappa statistic between interventions was 0.65, indicating a substantial level of agreement.

Conclusion This study demonstrated that electrophysiological stimulation using the Tsui technique is feasible for epidural catheter positioning in adults with chronic back pain. It may optimize epidural steroid injection in this population.

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Résumé

Objectif Il peut être difficile de déterminer le positionnement du cathéter péridural et de placer de façon précise les corticostéroïdes au site de la lésion chez les adultes souffrant de maux de dos chroniques. La fluoroscopie est considérée comme la norme de soins pour guider le positionnement du cathéter péridural et l'injection subséquente chez les patients recevant des corticostéroïdes par voie péridurale, mais la technique comporte certaines limites. Nous avons émis l'hypothèse que la stimulation électrophysiologique réalisée à l'aide du test de Tsui était faisable pour déterminer le positionnement adéquat du cathéter péridural chez les adultes souffrant de maux de dos

chroniques et recevant des corticostéroïdes par voie péri-durale.

Méthode Nous avons réalisé une étude de cohorte prospective auprès de 12 patients recevant des injections péri-durales de corticostéroïdes pour le traitement de maux de dos chroniques. Les repères anatomiques et les positions des aiguilles péri-durales ont d'abord été confirmés par fluoroscopie. Le positionnement du cathéter péri-dural a été évalué selon les réponses sensibles et motrices suivant l'application de courant électrique, lequel a été lentement augmenté de zéro jusqu'à observation d'une activité musculaire ou jusqu'à atteindre 10 mA. Le cathéter a ensuite été avancé jusqu'à la survenue de réponses musculaires dans le myotome souhaité. Le test a été jugé positif ou négatif selon les critères de Tsui. Le niveau anatomique a été confirmé par fluoroscopie avant l'injection.

Résultats La stimulation électrophysiologique a permis d'établir de façon efficace le positionnement adéquat du cathéter péri-dural chez 11 patients (92 %). La stimulation péri-durale est survenue à un seuil moyen (ÉT) de 3,95 (3,35) mA. L'indice kappa entre les interventions était de 0,65, ce qui indique un important degré de concordance.

Conclusion Cette étude a démontré que la stimulation électrophysiologique à l'aide de la technique de Tsui est faisable pour le positionnement du cathéter péri-dural chez l'adulte souffrant de maux de dos chroniques. Cette méthode pourrait optimiser l'injection péri-durale de corticostéroïdes chez cette population.

Chronic low back pain is routinely managed with epidural corticosteroids.^{1,2} To ensure an optimal response to this intervention, the injectate must be deposited within the epidural space in close proximity to the site of the pathology.³ The approaches commonly used to inject corticosteroid are 1) directly through an epidural needle or 2) via a catheter threaded into the epidural space.⁴ For both techniques, fluoroscopy is the standard of care to confirm that the epidural needle or catheter tip is properly positioned prior to injection.⁵⁻⁷ However, suboptimal corticosteroid placement is relatively common (23-53%) using fluoroscopy for confirmation, which can affect pain outcomes and patients' satisfaction.^{8,9}

With this problem in mind, Tsui et al. described an objective, reliable technique for confirming appropriate epidural catheter placement using electrophysiological stimulation. These investigators applied low-current electrical stimulation to nerves via an epidural catheter and assessed the patient's sensory and motor responses.¹⁰⁻¹² The Tsui test is considered positive (proper epidural catheter positioning) if there is a myotome response, either unilateral or bilateral, with a current of 1-10 mA and if the magnitude

of the response is independent of the placement of the ground electrode.¹⁰ The Tsui test is negative if a current of less than 1 mA elicits a motor response, which would imply either subarachnoid placement or placement against a nerve root. Motor responses of more than 10 mA suggest catheter placement outside the epidural space. The myotome level of the response to electrophysiological stimulation has been shown to correspond to the spinal column level of the epidural catheter's position.¹³

To date, the Tsui test has not been described for epidural catheter positioning in patients with chronic back pain. The intervention, however, has the potential to benefit individuals with pain whose symptoms do not correlate with the radiologically identified lesion. We hypothesized that it is feasible to apply electrophysiological stimulation with the Tsui test to determine the appropriate position for the epidural catheter tip in adults with chronic back pain receiving epidural corticosteroids. The primary outcome of our study was to establish the feasibility of using the Tsui test for epidural catheter placement in this population. A secondary outcome was to compare the optimal epidural catheter position using the Tsui test with the expected anatomical level using fluoroscopy.

Methods

With Research Ethics Board approval from St Michael's Hospital (May 2010), all patients aged > 18 yr with chronic back pain undergoing elective epidural injection of corticosteroids were assessed for eligibility from May 2010 to January 2011. An anesthesiologist independent of the research and interventional teams obtained informed written consent from the patients. Chronic back pain was defined as back pain of more than three months' duration that was not directly related to neoplastic involvement but was associated with a chronic medical condition or extending in duration beyond the expected temporal boundary of tissue injury and normal healing, and adversely affecting the function or well-being of the individual.¹⁴ The decision to proceed with epidural steroid injection was based on radiological imaging and the location and severity of the pain. Exclusion criteria included non-English-speaking persons, women of childbearing age, patients with implanted electronic devices, patient refusal, any contraindications to neuraxial intervention, and/or allergy to radiopaque contrast, corticosteroids, or local anesthetics.

After establishing standard monitoring and intravenous access, each patient was positioned prone. Anatomical landmarks were confirmed by fluoroscopy. The skin over the sacral hiatus was prepared using a sterile technique, and 5 mL of 1% lidocaine was infiltrated into the skin and

subcutaneous tissues overlying the sacral hiatus. A 17G Tuohy needle was inserted using a “loss of resistance to air” technique. The needle position was confirmed using fluoroscopy. A 19G catheter (Arrow Flex Tip Plus; Arrow International, Reading, PA, USA) was connected to a nerve stimulator via an adaptor (Johans ECG Adaptor; Arrow International).^{15,16} The catheter was filled with normal saline and advanced into the epidural space.

The epidural stimulation test was performed as described by Tsui et al.¹⁷ The anode lead of the nerve stimulator was connected to an electrode on the patient’s upper extremity. The nerve stimulator was set at a frequency of 1 Hz and a pulse width of 0.2 msec. The current was increased slowly from zero until lower limb muscle activity was visible or until the current reached a maximum of 10 mA. The catheter was advanced until muscle responses occurred in the desired myotome. The patient was questioned regarding pain at the targeted myotome level. A second observer documented motor responses. The test was deemed positive or negative according to the Tsui criteria.¹⁰ Positive criteria required that the current was within the range of 1–10 mA, the motor response could be unilateral or bilateral, and the motor response should be unchanged in terms of strength or location regardless of placement of the anode ground electrode. The catheter was deemed to be outside the epidural space if the patient did not respond, or the strength and location of the motor response changed with anode repositioning. The test was also deemed negative if the current required was less than 1 mA (indicating subarachnoid placement).^{10,18} The catheter was aspirated to rule out intrathecal or intravascular placement before the final position was confirmed. The duration of the procedure was defined as the time from first needle insertion to final confirmation of the position. The threshold current required to elicit a motor response at the final catheter position was recorded. More than three attempts at positioning using electrophysiological stimulation was considered a failure, and the Tsui test was stopped.

After a negative aspiration, 3 mL of contrast material (Omnipaque 240, GE Healthcare Inc., Princeton, NJ, USA) was injected. Distribution of the contrast medium was visualized using fluoroscopy. The catheter tip position was identified using anteroposterior and lateral radiological images. The anatomical position of the catheter tip was documented to the nearest upper vertebral level. A treatment solution of methylprednisolone 40 mg and 0.2% lidocaine 10 mL was injected incrementally through the epidural catheter.

The purpose of this study was to determine the feasibility of using electrophysiological stimulation with the Tsui test to guide epidural catheter positioning in adults with chronic back pain. Consequently, no formal sample size was calculated, but using data from other feasibility studies with the Tsui test to attain a sample size of 12 was deemed appropriate.^{11,12} Data

are reported as means and standard deviations or as medians and interquartile ranges as appropriate. The kappa statistic was used to test for agreement between the interventions. It was interpreted as: $\kappa < 0$, poor agreement; 0–0.2, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; 0.81–1.0, almost perfect.

Results

The demographic data of all participants are summarized in Table 1. The procedure was well tolerated by all patients, and no adverse effects were reported within six months of the intervention. The mean (standard deviation [SD]) time to perform each procedure was 21.6 (7.8) min. Epidural stimulation occurred at a mean (SD) threshold of 3.95 (3.35) mA. The median (interquartile range) number of attempts for repositioning were 2 (1–3). Ten catheters (83%) produced a unilateral response (Table 2). For one patient (Table 2; patient five) it was not possible to establish epidural placement using the Tsui test alone. The epidural position was subsequently confirmed using fluoroscopy, resulting in a success rate of 92%. The level of agreement between fluoroscopy and the Tsui test was substantial for the 11 successful participants. The kappa statistic (95% confidence interval) between techniques was 0.65 (0.26 to 1.04).

Discussion

This study investigated the feasibility of using electrophysiological stimulation with the Tsui technique for positioning the epidural catheter in adults with chronic

Table 1 Demographic data

Patient no.	Sex (male/female)	Age (yr)	ASA physical status classification
1	F	53	II
2	F	48	III
3	F	69	II
4	F	47	II
5	M	83	III
6	M	54	II
7	F	73	II
8	F	52	I
9	F	83	III
10	F	77	III
11	M	57	I
12	M	65	II

ASA = American Society of Anesthesiologists

Table 2 Summary of electrophysiological responses

Patient no.	Attempts (n)	Electrical threshold (mA)	Sensory or motor level elicited by Tsui test	Anatomical position of catheter tip	Response
1	3	6.0	L4-5	L4-5	Sensory and motor
2	3	1.9	L5-S1	L4-5	Sensory
3	2	1.5	L5-S1	L5-S1	Motor
4	2	3.0	L5-S1	L5-S1	Motor
5	3	n/a	n/a	L5-S1	No sensory or motor
6	2	6.0	L4-5	L3-4	Motor
7	1	1.5	L4-5	L4-5	Sensory and motor
8	1	10	L5-S1	L5-S1	Motor
9	3	4.0	L4-5	L4-5	Sensory and motor
10	2	2.0	L5-S1	L5-S1	Motor
11	2	10	L5-S1	L5-S1	Sensory
12	1	1.5	L5-S1	L5-S1	Sensory

n/a = not available

back pain who were receiving epidural corticosteroids. We showed a substantial level of agreement between electrophysiological stimulation using the Tsui technique and those using fluoroscopy in this population. The studied technique may have the potential to optimize the deposition of corticosteroids at the site of the pathology and consequently improve outcomes in this population.

Current guidelines recommend that interventionalists performing epidural injections aim to deposit corticosteroids in the ventral part of the epidural space, near the targeted nerve root.¹⁹ Epidural injections at the level of the lumbar spine are performed via caudal, transforaminal, and interlaminar routes. Caudal epidural injections are frequently performed using fluoroscopy guidance as it is considered the safest technique for this purpose, with minimal risk of dural puncture.⁴ We found, however, that the Tsui test may be used to deposit the corticosteroid dose more accurately at the site of pathology while retaining a safety profile similar to that seen with the traditional fluoroscopy-guided caudal approach to the epidural space.

The position of the epidural catheter tip has significant implications regarding clinical outcomes following epidural corticosteroid injections, and fluoroscopy has been widely cited as the standard of care for determining its position.^{20,21} Clinical outcomes are improved when the corticosteroid is deposited in close proximity to the site of pathology.⁹ Malpositioning can lead to intrathecal or intravascular injection of the corticosteroid, resulting in significant morbidity.²²

The disadvantages of fluoroscopy include ongoing radiation exposure for the patient and the risk of an allergic reaction to the radiopaque contrast material following repeated exposure.^{23,24} Use of fluoroscopy also adds significantly to the overall cost of the procedure.²⁵

Hogan et al. highlighted the inadequacies of radiological imaging to identify the proper position of the subdural catheter tip when performing epidural injections.²⁶ These positions can vary significantly, with the catheter frequently positioned lateral to the dura in the intervertebral foramen.²⁷ A recent American Society of Anesthesiologists Task Force on Chronic Pain Management found that there was still insufficient evidence to determine the clinical impact of image guidance when choosing the site of an epidural injection.¹⁴

Although fluoroscopy is still considered the standard of care for epidural catheter placement, alternative or complementary techniques could provide considerable benefit for patients who require deposition of epidural corticosteroids. The reliability of electrophysiological testing for epidural catheter placement has been confirmed in studies of obstetrical and pediatric patients.^{28,29} The technique has the advantage of offering physiological confirmation of the myotome level of the epidural catheter tip by demonstrating an appropriate motor response. Tsui et al. had a high success rate using electrical stimulation to guide catheter placement to the desired position in the epidural space.¹² Their technique has also been used successfully to guide placement of thoracic epidural catheters via the caudal route in small infants and children.^{28,30}

In our study, the Tsui test elicited isolated sensory responses in only three patients (3/12), with no motor responses. Two of the patients required threshold currents of 10 mA to elicit a response. Originally, Tsui et al. suggested a motor response threshold of 10 mA as the cutoff value to distinguish between epidural and nonepidural catheter locations. However, Tsui *et al.* recently confirmed that currents of more than 10 mA are required in some cases and may even reach upward of

17 mA.¹¹ There appears to be no current consensus as to the appropriate upper limit for the current, but there is agreement that the distribution of the motor response is more important than the actual current required.²⁸ Tsui et al. previously reported mean thresholds of 3.78 and 4.9 mA.¹¹ The time required to perform the procedure in our study was 21.6 min, which is comparable to the time needed to perform blind caudal corticosteroid injections (range 8–21 min).³¹

The notable limitation of our study is the small sample size. The project was designed as a feasibility study to aid future investigations regarding the effectiveness of this intervention. It had a sample size comparable to those of other feasibility studies using the Tsui test.^{11,12} Although the study was not powered to make comparisons between interventions, we found a substantial, but not statistically significant, correlation between the Tsui test and fluoroscopy for determining the appropriate position for the epidural catheter tip. We also used a compliant epidural catheter, which may have affected the accuracy of the positioning and consequently the procedure time. A directable catheter (such as those used for epidural neuroplasty) might have allowed greater speed and more maneuverability within the epidural space.³²

This study demonstrated that electrophysiological stimulation using the Tsui technique is feasible for positioning epidural catheters in adults with chronic back pain who require epidural corticosteroids. The procedure was well tolerated by all patients. Also, the patients were able to contribute to optimal positioning of the epidural catheter by providing feedback about sensory and motor symptoms during the procedure. This intervention has the potential to benefit individuals with pain whose symptoms do not correlate with the radiologically diagnosed lesion. There was a good correlation between electrophysiological stimulation using the Tsui technique and fluoroscopy in this population in regard to positioning the catheter tip. Further studies are required to determine whether this approach can improve patient outcomes.

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