

Detrusor Activity Is Impaired during Thoracic Epidural Analgesia after Open Renal Surgery

Patrick Y. Wuethrich, M.D.,* Thomas M. Kessler, M.D.,†
Jalesh N. Panicker, M.D., D.M., M.R.C.P. (UK),‡ Michele Curatolo, M.D., Ph.D.,§
Fiona C. Burkhard, M.D.||

ABSTRACT

Background: There are no data on lower urinary tract function during postoperative thoracic epidural analgesia (TEA). Because selected segmental blockade can be achieved with epidural analgesia, we hypothesized that lower urinary tract function remains unchanged during TEA within segments T4–T11 after open renal surgery.

Methods: In a prospective, open, observational, follow-up study, 13 male patients with no preexisting lower urinary tract symptoms (International Prostate Symptom Score ≤ 7) and postvoid residual less than 100 ml underwent urodynamic investigations the day before open renal surgery (lumbotomy) and 2–3 days postoperatively during TEA. Primary outcome was the difference in postvoid residual before *versus* after surgery during TEA.

Results: The median postvoid residual increased from 25 ml before surgery (range, 0–95) to 420 ml (15–1020) 2–3 days postoperatively ($P = 0.002$). Maximum detrusor pressure, detrusor pressure at maximum flow rate, and maximum flow rate were significantly reduced during TEA (37 [28–84] to 27 cm H₂O [13–51], $P = 0.004$; 31 [27–52] to 19 cm H₂O [0–33], $P = 0.003$; and 14 [4–35] to 4 ml/s [0–13], $P = 0.001$), respectively. Bladder capacity and sensation were not

changed during TEA. All patients had a postvoid residual determined by ultrasound of less than 100 ml 1 day after removal of the epidural catheter.

Conclusions: In contrast to our initial hypothesis, detrusor activity was significantly impaired during TEA after open renal surgery. This resulted in clinically relevant postvoid residuals.

What We Already Know about This Topic

- ❖ Lower urinary tract function after surgery may be affected by epidural analgesia, but this effect should be small or absent with segmental thoracic epidural analgesia

What This Article Tells Us That Is New

- ❖ In 13 male patients after open renal surgery and thoracic epidural analgesia with bupivacaine, fentanyl, and epinephrine, large postvoiding residual volume (420 ml) and evidence of detrusor weakness were observed
- ❖ Clinically significant lower urinary tract effects are commonly observed after surgery and thoracic epidural analgesia with this regimen

* Consultant in Anesthesia, § Head of Division of Pain Therapy, Department of Anesthesiology and Pain Therapy, † Consultant in Urology, || Senior Consultant in Urology, Department of Urology, University Hospital Bern, Berne, Switzerland. ‡ Consultant in Neurology, Department of Uro-Neurology, The National Hospital for Neurology and Neurosurgery, University College London Institute of Neurology, Queen Square, London, United Kingdom.

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Address correspondence to Dr. Wuethrich: Department of Anesthesiology and Pain Therapy, University Hospital Bern, CH-3010 Berne, Switzerland. patrick.wuethrich@insel.ch. Information on purchasing reprints may be found at www.anesthesiology.org or on the masthead page at the beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

ACUTE urinary retention is one of the most common complications after surgery and anesthesia.¹ Increased postvoid residuals can lead to various complications, and for this reason, a transurethral catheter is often placed perioperatively. However, the use of a transurethral catheter is associated with significant morbidity such as patient discomfort, urinary tract infections, urethral trauma, and stricture.^{2,3}

Epidural anesthesia is often continued postoperatively for pain control, and there is yet to be a consensus for the appropriate catheterization strategy in patients with an epidural catheter.^{4–6} Because the innervation of the bladder involves the segments L1–S4, it can be assumed that epidural analgesia within thoracic segments T4–T11 has no or minimal influence on lower urinary tract function. There are few studies evaluating the effects of various anesthetic agents on lower urinary tract function by urodynamic investigations, the majority of which focused on lumbar epidural anesthesia.^{7,8} To our knowledge, however, there are no data on lower urinary tract function during postoperative thoracic epidural analgesia (TEA).

We hypothesized that lower urinary tract function remains unchanged during epidural analgesia within segments T4–T11 after open renal surgery. Confirmation of our hypothesis would suggest that during TEA, an indwelling transurethral catheter, which is commonly left in place postoperatively, may be unnecessary in patients without preoperative lower urinary tract symptoms.

Materials and Methods

After obtaining approval from the local ethics committee of the University Hospital Bern (Bern, Switzerland) and informed patient consent, we prospectively evaluated 16 male patients with an American Society of Anesthesiologists physical status II–III who underwent a lumbotomy for open renal surgery. All patients completed the validated International Prostate Symptom Score questionnaire, which is used to assess lower urinary tract symptoms.⁹ Only patients with no preexisting lower urinary tract symptoms (International Prostate Symptom Score ≤ 7) and a postvoid residual less than 100 ml (assessed by ultrasound) were included. Three patients with a preoperative postvoid residual more than 100 ml were excluded. Thus, a total of 13 men were enrolled.

All patients received a TEA placed at the insertion site interspace T7–T8 or T8–T9. The insertion site was determined using the classic landmark method, whereby the spinal process of T7 is identified at the line intersecting the inferior tip of the scapulae in the sitting position. An 18-gauge epidural needle was inserted by a paramedian approach, and the epidural space was identified with the loss-of-resistance technique. After a test dose of 3 ml lidocaine, 20 mg/ml with 0.005 mg/ml epinephrine to rule out subarachnoid or intravascular placement, 2.5 mg/ml bupivacaine was administered intraoperatively *via* an infusion pump (ASENA, Alaris Medical System, Basingstoke, United Kingdom) at a rate of 6–10 ml/h. No opioids were administered epidurally during surgery. After administration of the test dose, general anesthesia was induced with propofol, fentanyl, and atracurium, and anesthesia was maintained with isoflurane. A transurethral catheter was inserted before surgery. At the end of surgery, continuous epidural analgesia was maintained with a mixture of 1 mg/ml bupivacaine, 2 μ g/ml epinephrine, and 2 μ g/ml fentanyl using a CADD Legacy ambulatory infusion pump (model 6300; Deltec Inc., St. Paul, MN). The initial infusion rate was 8 ml/h, with additional bolus volumes of 5 ml (lockout time: 1 h).^{10–13} The infusion rate was then adapted if necessary based on assessments made every 4 h to maintain a pain intensity lower than 3 at rest and lower than 5 during mobilization on the numeric rating scale, where 0 = no pain and 10 = worst pain imaginable. The maximum infusion rate was 15 ml/h. Paracetamol (1,000 mg) was administered for every 6 h as a supplement for postoperative analgesia. Potential risk factors for postoperative urinary retention (opioid requirement for analgesia, postoperative nausea and vomiting, and sedation) were documented. All methods, definitions, and units are in

accordance with the standards recommended by the International Continence Society.¹⁴

Patients underwent two urodynamic investigations, one on the day before surgery and the second 2–3 days postoperatively, depending on patient mobility, with epidural analgesia within segments T4–T11. All were performed according to good urodynamic practice.¹⁵ The area of sensory blockade was determined by loss of cold sensation using a cold pack (Nexcare reusable cold pack; 3M, St. Paul, MN). After placement of a 6-French transurethral dual channel catheter and a 14-French rectal balloon catheter (Gaeltec, Dunvegan, Scotland), the bladder was filled at a rate of 25–50 ml/min with Ringer's lactate solution at room temperature. Parameters of both the storage (bladder volume at first desire to void, bladder volume at strong desire to void, maximum cystometric capacity, bladder compliance, and detrusor overactivity) and the voiding (maximum detrusor pressure, detrusor pressure at maximum flow rate, maximum flow rate, voided volume, postvoid residual, and pelvic electromyographic activity) phase were recorded. Values obtained from the two consecutive urodynamic investigations performed in each patient were averaged for the data analysis. A TRITON multichannel urodynamic system (Laborie Medical Technologies Corp., Toronto, Canada) was used for all measurements.

Primary outcome was the difference in postvoid residual urine before and during TEA. On the basis of our hypothesis, a sample of 13 patients was needed to exclude differences in postvoid residual of 100 ml at a two-sided significance level of 5% with a statistical power of 90% and an SD of ± 100 ml (NCSS PASS program, NCSS, Kaysville, UT). Statistical analyses were performed with the Wilcoxon signed-rank test, and a *P* value of <0.05 was considered significant. SPSS version 15.0 (SPSS Inc., Chicago, IL) was used for statistical analyses.

Results

All data of the 13 patients were complete. The median age of the 13 male patients at the time of surgery was 67 yr (range, 51–79 yr), and the median International Prostate Symptom Score was 3 (0–7). Seven patients had an American Society of Anesthesiologists physical status class II, and six patients had an American Society of Anesthesiologists physical status class III. Six patients underwent an open partial nephrectomy, four patients an open nephrectomy, and three an open nephroureterectomy because of malignant tumors, all through a lumbotomy.

The area of the sensory blockade elicited by TEA extended from the thoracic dermatome T4 (T4–T6) to T11 (T10–T12). No motor neural blockade was present. The median numeric rating scale at rest was 0.0 (0–2) and at mobilization was 1.0 (0–4), with a median infusion rate of 8.0 ml/h (4–12). No patient dropped out because of inadequate epidural analgesia. No patient received intravenous opioids or sedatives postoperatively, and postoperative nausea and vomiting were not documented.

Table 1. Urodynamic Parameters of Voiding Phase before and during TEA

	Before (n = 13)	TEA	During (n = 13)	TEA	P Value
Postvoid residual, ml	25	(0–95)	420	(15–1,020)	0.002*
Voided volume, ml	510	(344–623)	85	(0–236)	0.001*
Maximum detrusor pressure, cm H ₂ O	37	(28–84)	27	(13–51)	0.005*
Detrusor pressure at maximum flow rate, cm H ₂ O	31	(27–52)	19	(0–33)	0.002*
Maximum flow rate, ml/s	14	(4–35)	4	(0–13)	0.001*

Data are presented as median (range).

* Wilcoxon signed-rank test with $P < 0.05$ as significant.

TEA = thoracic epidural analgesia.

The median postvoid residual increased from 25 ml (0–95 ml) preoperatively to 420 ml (15–1,020 ml) during TEA postoperatively ($P = 0.002$) (table 1). Voided volume decreased during TEA significantly ($P = 0.001$). Maximum detrusor pressure and detrusor pressure at maximal flow rate were significantly reduced during TEA (27 [13–51] cm H₂O vs. 37 [28–84] cm H₂O, [$P = 0.005$] and 19 [0–33] cm H₂O vs. 31 [27–52] cm H₂O, $P = 0.002$). Maximum flow rate decreased significantly from 14 ml/s (4–35 ml/s) to 4 ml/s (0–13 ml/s) ($P = 0.001$). Bladder compliance was significantly lower during TEA (28 ml/cm H₂O [16–127] vs. 71 ml/cm H₂O [40–180], $P = 0.01$). Bladder volume at first desire to void, at strong desire to void, and at maximum cystometric capacity did not differ significantly (table 2).

Pelvic floor electromyographic activity was normal preoperatively and during TEA. There were no transient or permanent neurologic symptoms. All thoracic epidural catheters were removed on the fifth or sixth postoperative day. All patients had a postvoid residual lower than 100 ml 1 day after removal of the epidural catheter, as determined by ultrasound.

Discussion

To our knowledge, we are the first to assess lower urinary tract function during postoperative TEA. In contrast to our working hypothesis, TEA after open renal surgery was associated with a significant impairment in detrusor activity with clinically relevant postvoid residuals.

Postvoid residuals can lead to various complications, ranging from urinary tract infections, bladder stones, and bladder distension to kidney failure caused by ascending in-

fections or hydronephrosis.¹⁶ Since the pioneering study by Abrams *et al.*¹⁷ in 1978, a cutoff value of 300 ml for postvoid residuals has become widely accepted as clinically significant. However, newer studies evaluating the clinical relevance of postvoid residuals have found lower volumes (180 ml) to be clinically relevant.¹⁸ A significant positive correlation between postvoid residual and urinary tract infection has been reported,¹⁹ and overdistension as a result of unrecognized postvoid residual can cause significant impairment of bladder function.²⁰ Given the aforementioned data, the median postvoid residual of 420 ml observed in our study represents a clinically significant impairment that requires treatment in most cases.

Micturition depends on coordinated actions between the detrusor and the external urethral sphincter. Motor neurons of both muscles are located in the sacral spinal cord, and the coordination between them occurs in the pontine tegmentum of the caudal brainstem. Motor neurons innervating the external urethral sphincter are located in the nucleus of Onuf, extending from segments S1 to S3. The detrusor smooth muscle is innervated by parasympathetic fibers, which reside in the sacral intermediolateral cell group and are located in S2–S4. Sympathetic fibers innervating the bladder and urethra play an important role in promoting continence and are located in the intermediolateral cell group of the lumbar cord (L1–L4). Most afferent fibers from the bladder enter the sacral cord through the pelvic nerve at segments L4–S2, and the majority is thinly myelinated or unmyelinated.

The few studies on the urodynamic effects of various anesthetic agents mainly focus on lumbar epidural and spinal

Table 2. Urodynamic Parameters of the Storage Phase before and during TEA

	Before (n = 13)	TEA	During (n = 13)	TEA	P Value
Bladder volume at first desire to void, ml	290	(150–780)	330	(110–690)	0.97
Bladder volume at strong desire to void, ml	440	(300–950)	460	(135–1,000)	0.64
Bladder compliance, ml/cm H ₂ O	70	(40–180)	30	(16–127)	0.01*
Maximum cystometric capacity, ml	560	(310–950)	490	(180–1,020)	0.37

Data are presented as median (range).

* Wilcoxon signed-rank test with $P < 0.05$ as significant.

TEA = thoracic epidural analgesia.

anesthesia.^{7,8,21–25} During the influence of lumbar epidural analgesia, patients may not feel the urge to urinate, which can result in urinary retention and bladder overdistension. For example, the use of lumbar epidural analgesia for delivery has frequently been implicated as a causative factor for postpartum urinary retention.⁷ Lumbar epidural and spinal morphine administration influence lower urinary tract function by direct spinal action on the sacral nociceptive neurons and autonomic fibers.²⁶ Long-acting local anesthetics such as bupivacaine administered intrathecally rapidly block the micturition reflex. Detrusor contraction is restored approximately 7–8 h after spinal injection of bupivacaine.²⁷ Bladder catheterization is a common practice in patients with lumbar epidural or spinal anesthesia because of impaired bladder sensation and impaired voiding function.

It is not clear why blockade of the nerves at the thoracic level was associated with impaired voiding function. Thoracic segmental sympathetic blockade is accompanied by intact sympathetic activity in the intact T12–L1 level.²⁸ A potential increase in lumbar sympathetic reflex activity or postoperative stress-induced activation thereof may have influenced detrusor activity. Alternatively, possible lumbar spread of anesthesia and preferential susceptibility of small thinly myelinated fibers to the effect of local anesthesia compared with larger A α fibers conveying sensations could have resulted in selective autonomic involvement.²⁹ Bladder capacity was not influenced by TEA, and bladder sensation was evident in all patients at maximal bladder capacity, which may be attributed to intact sacral innervation. The limiting factor for voiding function during TEA seems to be the strength of detrusor contraction.

The site of action of epidurally administered fentanyl remains controversial and probably depends on the mode of administration (bolus *vs.* infusion) and the level at which the epidural catheter is inserted. Most reports relate to lumbar epidural analgesia and were published more than 20 yr ago; data on the effect of fentanyl applied epidurally at the thoracic level are lacking.^{30,31} Continuous epidural infusion of lipophilic opioids, such as fentanyl, leads to equal spinal and supraspinal analgesia because of drug redistribution to the brain.^{32,33} Opioids applied intravenously inhibit detrusor function and stimulate urethral sphincter tonus, resulting in a hypocontractile bladder and urinary retention.³⁴ Conversely, addition of fentanyl to 0.2% ropivacaine for peripartum epidural analgesia did not increase the risk of urinary retention.³⁵

Niemi and Breivik¹¹ demonstrated that the serum concentration of fentanyl was halved by adding epinephrine to the bupivacaine and fentanyl concentrations used in the current study, resulting in a fentanyl serum concentration of 0.22 ng/ml. This concentration was lower than the mean minimum effective systemic analgesic concentration.¹² On the basis of these data, we find it unlikely that the dramatic impairment in voiding function was the result of systemic absorption of epidural fentanyl. Nevertheless, the effect of

low-dose epidural fentanyl on lower urinary tract function remains unclear and needs further investigation.

Similarly, the effect of epidurally applied epinephrine on lower urinary tract function is at present unknown. We find it unlikely that such low doses, administered at the thoracic level, account for our findings. Another potential cause of voiding dysfunction is surgery. However, we are not aware of either clinical or pathophysiologic data that support a major role of open renal surgery on detrusor activity. The normalization of postvoid residuals after discontinuation of TEA suggests that TEA, rather than surgery, had a major influence on lower urinary tract function, but the before–after nature of our study does not allow a definite conclusion regarding this issue.

The current study has one main limitation: it cannot provide clear explanations for the observed changes in lower urinary tract function. However, it presents a novel and clinically relevant finding and may represent the basis to stimulate mechanistic research in this field. To explain the mechanisms that underlie voiding dysfunction during postoperative TEA, randomized controlled trials need to be performed.

In summary, TEA with segmental blockade T4–T11 after open renal surgery was associated with impaired detrusor activity with significantly increased postvoid residuals, of which the majority were clinically relevant.

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