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REVIEW ARTICLE/BRIEF REVIEW

Neuraxial anesthesia and bladder dysfunction in the perioperative period: a systematic review

Anesthésie neuraxiale et dysfonction vésicale en période périopératoire: une revue systématique

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Abstract

Purpose *Urinary retention requiring catheterization carries the risk of infection. Neuraxial anesthesia causes transient impairment of bladder function ranging from delayed initiation of micturition to frank urinary retention. We undertook a review of the literature to determine the elements of neuraxial anesthesia and analgesia that prolong bladder dysfunction and increase the incidence of urinary retention.*

Methods *We performed a systematic search of the PubMed, MEDLINE, and EMBASE databases (from January 1980 to January 2011) to identify studies where neuraxial anesthesia and/or analgesia were employed and at least one of the following outcomes was reported: urinary retention, time to micturition, or post void residual. We included randomized controlled trials and observational studies published in the English language and we excluded case reports. The randomized trials were graded according to the Jadad score.*

Principal findings *Our search yielded 94 studies, and in 16 of these studies, the authors reported time to micturition after intrathecal anesthesia of varying local anesthetics and doses. Intrathecal injections were performed in 41 of these studies, epidural anesthesia/analgesia was used in 39 studies, and five studies involved both the intrathecal and epidural routes. Meta-analysis was not possible because of the heterogeneity of interventions and reported outcomes. The duration of detrusor dysfunction after intrathecal anesthesia is correlated with local anesthetic dose and potency. The incidence of urinary retention displays a similar trend and is further increased by the presence of neuraxial opioids, particularly long-acting variants. Urinary tract infection secondary to catheterization occurred rarely.*

Conclusions *Neuraxial anesthesia/analgesia results in transient detrusor dysfunction. The duration of dysfunction depends on the potency and dose of medication used; however, it does not appear to result in significant morbidity.*

Résumé

Objectif *Une rétention urinaire nécessitant un cathétérisme s'accompagne du risque d'infection. L'anesthésie neuraxiale provoque un trouble transitoire de la fonction vésicale allant du début retardé de la miction à la rétention urinaire franche. Nous avons entrepris une revue de la littérature pour déterminer les éléments de l'anesthésie et de l'analgésie neuraxiales qui prolongent la dysfonction vésicale et augmentent l'incidence de la rétention urinaire.*

Méthodes *Nous avons effectué une recherche systématique dans les bases de données PubMed, MEDLINE et EMBASE (de janvier 1980 à janvier 2011) pour identifier des études dans lesquelles une anesthésie et/ou une analgésie neuraxiales ont été employées avec la description d'au moins l'un des résultats suivants: rétention urinaire, retard de miction, volume résiduel post mictionnel. Nous avons inclus*

Author contributions *Imad Awad* is the senior responsible author who conceived this project. *Stephen Choi* had primary responsibility for preparing the manuscript, and *Padraig Mahon* had a significant role in preparing the manuscript. *Stephen Choi* and *Padraig Mahon* performed the literature search, and *Stephen Choi*, *Padraig Mahon,* and *Imad Awad* reviewed the studies.

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les essais randomisés contrôlés et les études observationnelles publiées en anglais et avons exclu les comptes rendus de cas. Les essais randomisés ont été cotés selon le score de Jadad.

Constatations principales *Notre recherche a rassemblé 94 études et des retards de miction ont été décrits par les auteurs dans 16 de ces études, après anesthésie intrathécale avec différents anesthésiques locaux à des posologies variables. Des injections intrathécales ont été réalisées dans 41 de ces études; une anesthésie/analgésie épidurale a été utilisée dans 39 études; et les deux voies (intrathécale et épidurale) ont été utilisées dans cinq études. Une méta-analyse n'a pas été possible en raison de l'hétérogénéité des interventions et des résultats décrits. La durée des troubles dysfonctionnels du détrusor après anesthésie intrathécale est corrélée à la dose et à la puissance de l'anesthésique local. L'incidence de la rétention urinaire affiche une tendance comparable et est encore augmentée par la présence neuraxiale de morphiniques, en particulier de leurs formes à longue durée d'action. Les infections des voies urinaires après un cathétérisme ont été rares.*

Conclusions *L'anesthésie/analgésie neuraxiale entraîne une dysfonction transitoire du détrusor. La durée des troubles fonctionnels dépend de la puissance et de la posologie du médicament utilisé; toutefois, cela ne semble pas se traduire par une morbidité significative.*

Neuraxial anesthesia can result in significant bladder denervation in the perioperative period and can subsequently precipitate urinary retention.[1] The dysfunction associated with this transient effect ranges from mild (with delayed initiation of micturition and incomplete bladder emptying) to severe (with urinary retention and bladder overdistension). When alleviated with catheterization, urinary retention can increase morbidity by introducing infection and increasing the length of hospital stay.[2-5]

Urinary retention is the inability to initiate micturition or to empty the bladder completely. There are no clear defining characteristics of urinary retention, such as a specific volume of urine or elapsed time postoperatively without micturition; however, in accordance with the consensus view in the contemporary literature, urinary retention would be described as an inability to initiate micturition with a bladder volume exceeding 500 mL.[6] Urinary retention can be complete or partial, acute or chronic, painful or silent, obstructive or non-obstructive. "Overflow" incontinence secondary to excess intravesical pressure can occur. *De novo* incontinence secondary to sphincter damage, detrusor overactivity (urgency), or stress (precipitated by increased intra-abdominal pressure) developing in the perioperative period are uncommon occurrences. The long-term consequences of postoperative urinary retention (POUR) are not always immediately apparent in the perioperative period, although increased hospital length of stay and prolonged detrusor dysfunction have been documented.[1,6]

Neuraxial local anesthetics block the afferent and efferent limbs of the micturition reflex resulting in detrusor dysfunction and the inability to sense a full bladder, thus impairing micturition. Neuraxial opioids enhance this effect by decreasing the sensation of bladder fullness, thus increasing bladder capacity and weakening detrusor contraction through their actions at the spinal level and in the pontine micturition centre.[7-9] Other previously identified perioperative and preexisting risk factors for urinary retention include age, type of surgery, drug side effects, and benign prostatic hypertrophy, but none usually results in the transient, though dense, dysfunction caused by neuraxial anesthesia.

This study was initiated because a recent review on urinary retention did not focus specifically on urinary retention after neuraxial anesthesia and/or analgesia.[1] The extensive work by Baldini *et al.* is a narrative review wherein they aim to give the reader a broad overview of the clinical problem.[1] In the present study, we attempt to go beyond a narrative review and perform a systematic assessment of urinary outcomes, including time to micturition, incidence of catheterization, and subsequent frequency of urinary tract infection after neuraxial intervention. The primary aim of this review is to determine the incidence of urinary retention and any associated morbidity in patients following neuraxial anesthesia or analgesia and to identify risk factors prolonging impaired micturition.

Methods

A systematic search of the PubMed, MEDLINE, and EMBASE databases was performed from January 1980 to January 2011 using the medical subject heading (MeSH) words "neuraxial anesthesia" or "neuraxial analgesia" or "epidural" or "intrathecal" or "spinal". These were combined with the MeSH terms "urinary retention" or "urinary incontinence" or "urinary catheterization" or "micturition" or "post void residual". The search was limited to articles published in the English language and human adults. Each abstract was evaluated to identify studies where neuraxial anesthesia was utilized and urinary retention, or time to micturition, or post void residual was reported as an outcome. The references of the retrieved articles were hand searched for any relevant studies not captured in the original search. In addition to randomized controlled trials (RCTs), observational studies were also included because of the limited amount of data present in the literature.

Studies included in the review were categorized according to modality of neuraxial anesthesia – intrathecal or epidural. Studies involving combined spinal-epidural techniques were grouped with those utilizing epidural techniques because the effects of the epidural infusion typically outlast the effects of the intrathecal component. Studies were included even if patients did not undergo surgical procedures but were volunteers for urodynamic studies. Data were abstracted using a template created independently to identify the following information: primary author with year of publication, study design, Jadad score for RCTs, number of patients, surgical class, neuraxial medication employed (local anesthetic only, local anesthetic with short- or long-acting opioid, opioid only, undefined), incidence of urinary retention, average time to first micturition, and post void residual (PVR). If reported in the source study, we also abstracted the number of patients requiring catheterization and the incidence of urinary tract infection. Where possible, we reported the statistical significance for the incidence of urinary retention between comparators.

With each neuraxial technique, studies were further subdivided into the following categories: local anesthetic only, local anesthetic with long-acting opioid, local anesthetic with short-acting opioid, and undefined.

The methodology of each RCT was graded according to the criteria published by Jadad *et al.*[10] All RCTs were included regardless of grade, and observational studies were not graded because it became clear after the initial literature review that the level of methodological rigour and study methods were so variable that meta-analysis would not be feasible or appropriate given that there is no easily communicated standard for grading observational studies. Two of the authors (S.C., P.M.) independently performed the literature search and data extraction. Results were combined and differences were resolved through discussion amongst the three authors (S.C., P.M., I.A.).

Results

Initially, 4,465 references were retrieved, and the search yielded 3,662 abstracts when limited to the English language and human subjects. Each abstract was reviewed, but it was not utilized if it did not state clearly that urinary retention, or PVR, or time to micturition was recorded as an outcome. If the abstract did not state specifically that spinal/epidural anesthesia and/or analgesia were employed, it was not retained.

We identified 94 studies (11,162 patients) where neuraxial anesthesia or analgesia was employed and where urinary retention, time to micturition, or PVR was reported as an outcome (Figure). Meta-analysis was not performed owing to the heterogeneity of the definitions of urinary retention, if at all

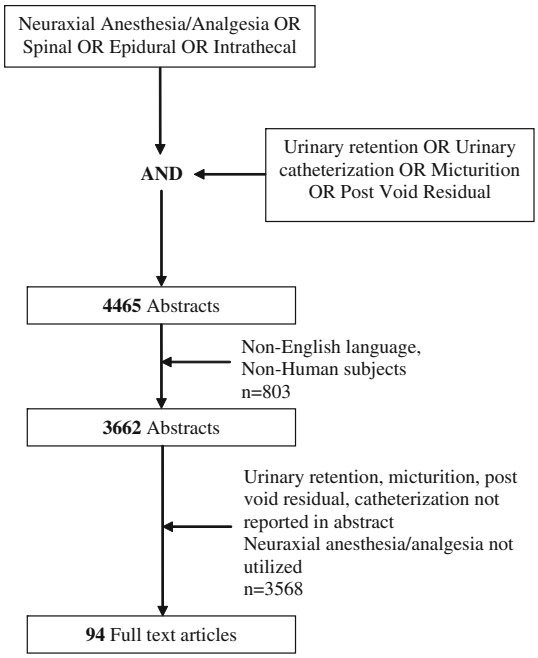

Figure Flow chart of screened, excluded, and included studies

provided, and the significant variability in the dose, type, and use of opioids in the neuraxial medications utilized.

In 16 of the 94 RCTs (1,066 patients), time to return of spontaneous micturition after intrathecal anesthesia was assessed as a primary outcome (Table 2).[11-26] In 41 studies (5,548 patients), urinary retention or PVR with intrathecal anesthesia was assessed (Table 3),[11,13,16,17,20,22,27-65] and in 39 studies (4,938 patients), urinary retention or PVR with epidural anesthesia and/or analgesia was assessed (Table 4).[28,33,35,43,48-50,54,66-100] An additional five studies involved both intrathecal and epidural techniques. There is overlap in the numbers of patients/studies reported for Tables 2, 3, and 4 because multiple outcomes and/or multiple neuraxial procedures were examined in several studies. The characteristics of the included studies are detailed in Table 1. Among the 94 studies, 54 of the included studies were RCTs, 27 were prospective observational studies, and 13 were retrospective reviews. None of the included studies designated urinary retention as a primary outcome measure. Among the 94 studies, two studies investigated spinal anesthesia in volunteers with no surgical procedure performed.[15,24]

Of the 55 studies (including 16 RCTs in Table 2) reporting a urologic outcome after intrathecal anesthesia, 41 specifically assessed the incidence of urinary retention, 27 assessed for rate of catheterization, 16 assessed time to micturition, six reported rates of infection, and one reported PVR. Only 25 studies defined criteria for urinary retention. The criteria ranged from quoting bladder volumes (from 150-600 mL) or time frames (from 30 min to two days) to

Table 1 Characteristics of the 94 studies retained for analysis

	Number (*n*)	Percentage (%)
Study type		
Randomized trial	54	57
Observational study	27	29
Retrospective review	13	14
Jadad score (for RCTs)		
5	16	30
4	3	6
3	25	46
2	5	9
1	5	9
Type of neuraxial procedure		
Spinal only	51	54
Epidural only	39	41
Both spinal and epidural	5	5
Urologic outcome reported*		
Urinary retention	79	84
Time to micturition	25	28
Post void residual	4	5
Catheterization	64	68
Urinary tract infection	13	14
Urologic outcome as primary outcome		
Urinary retention	0	0
Time to micturition	16	17
Post void residual	0	0
Urinary Retention		
Defined	43	46
Undefined	37	39
Not applicable	14	15
Neuraxial medication type/dose		
Reported	74	79
Local anesthetic only	35	47
Local anesthetic + Opioid	31	43
Opioid only	9	10
Not Reported	20	21
Number of subjects		
< 50	42	44
51-100	31	35
101-150	8	8
151-200	7	7
> 200	6	6

n = number of studies; RCT = randomized controlled trial; *Due to instances where multiple urologic outcomes were reported, some studies were counted more than once

stating that catheterization was necessary without describing indications or that urinary retention was simply as inability to void without other defining criteria (Table 3).

Forty-two of the 44 studies reporting a urologic outcome after epidural analgesia specifically assessed the incidence of urinary retention. Similarly, only 26 studies defined criteria for urinary retention, but these criteria were as varied as those in the studies reporting intrathecal anesthesia. Thirty-one studies reported catheterization rates, seven reported infection rates, and only one reported PVR.

Local anesthetic type and dose

The incidence of POUR appears correlated with the specific intrathecal local anesthetic utilized. The studies reporting incidence rates of > 20% were those utilizing either tetracaine or bupivacaine, while those employing procaine or lidocaine reported incidence rates < 20% (Table 3). The studies utilizing epidural analgesia are difficult to assess in this respect because of the highly variable durations of infusion (Table 4).

The 16 RCTs that specifically examined time to return of spontaneous micturition after intrathecal anesthesia as a primary outcome assessed several local anesthetics in differing concentrations, densities, and doses (Table 2). The time to first micturition varied from 103 min[15] (2-chloroprocaine) to 462 min (bupivacaine).[18] We did not perform a linear regression analysis of the micturition time based on dose because we considered that the varying densities and concentrations utilized would confound the results. Seeing as widely varying doses, concentrations, and densities were utilized even within groups, we did not combine the results of each local anesthetic.

Time to spontaneous micturition correlates with the potency of the local anesthetic administered intrathecally, and it correlates with dose for each specific local anesthetic. Kamphuis *et al.* showed this with filling cystometric studies comparing bupivacaine with lidocaine.[18] The longer lasting and more potent bupivacaine was associated with longer detrusor dysfunction (462 min) compared with lidocaine (233 min). This difference becomes more apparent when varying doses of the same medication (concentration and density) are compared within studies. Ben-David *et al.*, Urmey *et al.*, Kallio *et al.*, and Casati *et al.* showed this with bupivacaine, lidocaine, articaine, and 2-chloroprocaine, respectively.[11,22,25,26] The longest times to spontaneous micturition after intrathecal anesthesia with each of bupivacaine, lidocaine, articaine, and 2-chloroprocaine were 462 min, 260 min, 279 min, and 271 min, respectively.[18,19,21,26]

Neuraxial opioids

The effects of intrathecal or epidural opioids on bladder function are similar to those of local anesthetics in that the potency and dose of the opioid appears to predict the duration of bladder dysfunction. Morphine in conjunction with intrathecal anesthesia was utilized in only two studies,

Table 2 Studies with time to micturition as an outcome after intrathecal local anesthetics

Intrathecal Drug Type and Author/Year	Drug Dose (mg)	Concentration	Baricity	Number of Patients	Opioid	Time (min) to Micturition Mean (SD)	Required catheterization
Total (1,066 patients)							
Bupivacaine (368 patients)							
Dijkstra 2008[14]	15	0.5%	Iso	38	-	350 (N/A)	N/A
Ben-David 1996[11]	15	0.5%	Hyper	15	-	428 (34)	N/A
Ben-David 1996[11]	10	0.33%	Hyper	15	-	241 (14)	N/A
Kamphuis 2008[18]	10	0.75%	Hyper	10	-	462 (61)	N/A
Lacasse 2011[21]	7.5	0.75%	Hyper	53	-	338 (99)	N/A
Gupta 2003[16]	7.5	0.5%	Hyper	20	Fent 25 μg	335 (N/A)	4/20
Yoos 2005[24]	7.5	0.5%	Iso	8	-	191(32)	N/A
Ben-David 1996[11]	7.5	0.25%	Hyper	15	-	186 (14)	N/A
Gupta 2003[16]	6	0.5%	Hyper	20	Fent 25 μg	268 (N/A)	3/20
Valanne 2001[23]	6	0.5%	Hyper	51	-	203 (N/A)	N/A
Kuusniemi 2000[20]	6	0.5%	Hyper	30	-	228 (60)	N/A
Kuusniemi 2000[20]	6	0.5%	Iso	30	-	252 (60)	N/A
Ben-David 1996[11]	5	0.16%	Hyper	15	-	163 (8)	N/A
Valanne 2001[23]	4	0.5%	Hyper	48	-	172 (N/A)	N/A
L-bupivacaine (30 patients)							
Breebaart 2003[13]	10	0.33%	Iso	30	-	284 (57)	1/30
Ropivicaine (30 patients)							
Breebaart 2003[13]	10	0.5%	Iso	30	-	285 (65)	1/30
Lidocaine (315 patients)							
Kamphuis 2008[18]	100	2%	Hyper	10	Sufent 20 μg	332 (52)	N/A
Kamphuis 2008[18]	100	2%	Hyper	10	-	233 (31)	N/A
Urmey 1995[22]	80	2%	Iso	29	-	215 (73)	N/A
Breebaart 2003[13]	60	2%	Iso	30	-	245 (65)	0/30
Urmey 1995[22]	60	2%	Iso	32	-	193 (30)	N/A
Ben-David 2000[12]	50	1%	Hypo	55	-	200 (102)	N/A
Urmey 1995[22]	40	2%	Iso	29	-	159 (36)	N/A
Kawamata 2003[19]	30	3%	Hyper	32	-	260 (N/A)	N/A
Kawamata 2003[19]	30	1%	Hyper	33	-	200 (N/A)	N/A
Ben-David 2000[12]	20	1%	Hypo	55	Fent 25 μg	188 (87)	N/A
Prilocaine (36 patients)							
Hendriks 2009[17]	50	2%	Iso	36	-	227 (45)	2/36
Articaine (165 patients)							
Kallio 2006[26]	100	4%	Hyper	30	-	279 (N/A)	N/A
Dijkstra 2008[14]	100	5%	Hyper	39	-	257 (N/A)	N/A
Kallio 2006[26]	84	4%	Hyper	30	-	271 (N/A)	N/A
Kallio 2006[26]	60	4%	Hyper	30	-	249 (N/A)	N/A
Hendriks 2009[17]	36	2%	Iso	36	-	184 (39)	1/36
2-Chloroprocaine (114 patients)							
Casati 2006[25]	50	2%	Iso	15	-	203 (N/A)	N/A
Lacasse 2011[21]	40	2%	Iso	53	-	271 (87)	N/A
Yoos 2005[24]	40	2%	Iso	8	-	113 (14)	N/A
Casati 2006[25]	40	2%	Iso	15	-	198 (N/A)	N/A
Casati 2006[25]	30	2%	Iso	15	-	182 (N/A)	N/A
Gonter 2005[15]	30	1.5%	Hyper	8	-	103 (12)	N/A

Table 2 continued

Intrathecal Drug Type and Author/Year	Drug Dose (mg)	Concentration	Baricity	Number of Patients	Opioid	Time (min) to Micturition Mean (SD)	Required catheterization
Procaine (8 patients)							
Gonter 2005[15]	80	4%	Hyper	8	-	156 (23)	N/A

Fent = fentanyl; Hyper = hyperbaric; Hypo = hypobaric; Iso = isobaric; N/A = not available; SD = standard deviation; Sufent = sufentanil

both non-randomized, and the reported incidence rates of urinary retention were 36% and 25%, respectively.[45,64] In contrast, studies in which either intrathecal fentanyl or sufentanil was utilized reported lower incidence rates ranging from 0 to 25%.[12,16,18,46,48,57,61] Kamphuis *et al.* showed that the addition of sufentanil 20 μg prolonged the detrusor dysfunction associated with intrathecal lidocaine 100 mg from 233 to 332 min.[18]

A similar pattern occurred with neuraxial opioids and epidural analgesia, though the pattern is less distinct (Table 4). Ten studies utilizing long-acting opioids reported incidence rates of 9.2-79.5% (only three studies showed rates < 40%). In 15 studies on short-acting opioids, the rate of urinary retention ranged from 0% to 40%.

Comparison with other anesthetic modalities

Only five studies made comparisons with other anesthetic modalities. Schmittner *et al.* compared intrathecal with general anesthesia and found no difference in time to micturition.[56] Casati *et al.* also found no difference between intrathecal, general, or peripheral nerve block anesthesia in terms of time to micturition.[25] Sungurtekin *et al.* found no difference between intrathecal anesthesia and local infiltration, while van Veen *et al.*, Young *et al.*, and Anannamchareon *et al.* reported significantly higher rates of urinary retention with intrathecal anesthesia compared with local infiltration.[27,58,61,63]

Urinary tract infection

Thirteen of the 94 studies included in this review reported the incidence of urinary tract infection associated with catheterization.[28,30,40,61,63,64,66,69,73,75,76,89,100] Six of these reported no infections while seven studies reported rates of < 10%.

Discussion

Our review of the literature identified several themes with respect to the effects of neuraxial anesthesia and analgesia on POUR and other urinary outcomes. First, the potency/dose of local anesthetic and the presence of opioids affect detrusor dysfunction and the time to return of spontaneous micturition. This time period lasts as long as 462 min (bupivacaine) or is as short as 103 min (2-chloroprocaine). With long-acting epidural opioids, the reported incidence of urinary retention is as high as 79.5%. Second, whether detrusor dysfunction specifically results in POUR is unclear, but the incidence of POUR, at least after single-dose intrathecal anesthesia, is low, and complications, such as urinary tract infections, are even less frequent. Complications (urinary tract infection) associated with POUR after epidural analgesia also surface infrequently. However, there are inherent limitations to our analysis. Few of the included studies are randomized trials that compare general with neuraxial anesthesia and include urinary retention as a primary outcome. Furthermore, we included all RCTs regardless of Jadad score and did not grade observational studies to highlight the inadequacy of the current evidence with methodologically sound studies assessing this clinical issue. Indeed, the heterogeneity of definitions and anesthetic management further hampers any ability to offer more quantitative analysis.

Our conclusions must be viewed cautiously owing to several factors, including the aforementioned varying definitions used by the included studies to define urinary retention and the significant heterogeneity in local anesthetic type/dose and opioid doses. Several studies, though implicating intrathecal anesthesia as a risk factor for urinary retention, neither discuss a comparative anesthetic modality nor provide the dose/type of local anesthetic utilized.[28,30,33,36,41,43,52-55]

Results of studies assessing the urodynamic effects of both intrathecal local anesthetics and opioids tend to concur with our data. Kamphuis *et al.* performed filling cystometric studies in 30 male patients to estimate detrusor pressure and flow rates.[18] The studies were performed both prior to and following intrathecal anesthesia with hyperbaric lidocaine (100 mg) with or without sufentanil (20 μg) or with hyperbaric bupivacaine (10 mg). Patients' bladders were filled at a constant rate of 50 mL•min^{-1} when supine, and filling was stopped when a strong desire to void was felt (the cystometric capacity ~ 500 mL). The urge to void disappeared within 60 sec of the start of injection of intrathecal anesthetic. The recovery of the ability to void normally (using only detrusor muscle, generating

Table 3 Intrathecal anesthesia studies

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Total 5,548 patients										
Local anesthetic only (4,662 patients)										
Tetracaine										
Carpiniello 1988[30]	OBS	N/A	77	ORTHO	Tetracaine dose N/A	34/77 (44.1)	N/A	34/77 (44.1)	8/77 (10.4)	Retention defined as requiring catheterization
Ryan 1984[54]	REV	N/A	25	GEN	1. Lidocaine dose N/A ($n = 4$)	1. 0/4 (0)	N/A	1. 0/4 (0)	N/A	Retention defined as requiring catheterization
					2. Tetracaine dose N/A ($n = 21$)	2. 6/21 (28.6)		2. 6/21 (28.6)		*See Table 4 – long-acting spinal/epidural 16/53
Bupivacaine										
Ben-David 1996[11]	RCT	3	60	ORTHO	Hyperbaric Bupivacaine 0.5%		N/A	N/A	N/A	Retention not defined
					1. 15 mg ($n = 15$)	1. 0/15 (0)				
					2. 10 mg + 1 mL NS ($n = 15$)	2. 0/15 (0)				
					3. 7.5 mg + 1.5 mL NS ($n = 15$)	3. 0/15 (0)				
					4. 5 mg + 2 mL NS ($n = 15$)	4. 0/15 (0)				
Farag 2005[35]	RCT	1	22	ORTHO	Bupivacaine 15 mg	0/22 (0)	N/A	0/22 (0)	N/A	Retention not defined Compared with epidural ropivacaine
Moreno-Egea 2000[47]	OBS	N/A	41	GEN	Hyperbaric Bupivacaine 0.5% 13 mg	1/41 (2.4)	N/A	N/A	N/A	Retention not defined
Jellish 1996[37]	RCT	3	61	ORTHO	Hyperbaric Bupivacaine 0.75% 11 mg	9/61 (14.8)	N/A	9/61 (14.8)	N/A	Retention defined as requiring catheterization, volume/time not specified
Anannamcharoen 2008[27]	RCT	3	67	GEN	Hyperbaric Bupivacaine 0.5% 7.5-10 mg ($n = 33$)	10/33 (30.3)	N/A	10/33 (30.3)	N/A	Retention not defined In favour of local infiltration for incidence of retention and requirement for catheterization ($P = 0.03$)

Table 3 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Casati 2004[31]	RCT	3	120	ORTHO	Hyperbaric Bupivacaine 0.5% 8 mg ($n = 40$)	3/40 (7.5)	N/A	N/A	N/A	Significant difference in retention ($P = 0.03$) compared with TIVA or combined FEM/SCI Significant difference in time to micturition ($P < 0.0005$) spinal *vs* other groups (260 *vs* 145-180 min)
Fanelli 2000[34]	RCT	3	94	ORTHO	Hyperbaric Bupivacaine 0.5% 8 mg	0/94 (0)	N/A	N/A	N/A	Retention defined as the inability to initiate micturition within 6 hr
Luger 2008[44]	OBS	N/A	45	ORTHO	Hyperbaric Bupivacaine 0.5% 6-7.5 mg	14/45 (31.1)	N/A	14/45 (31.1)	N/A	Retention defined as bladder volume > 500 mL by US or inability to void 4 hr after intrathecal injection
Esmaoglu 2004[32]	RCT	1	70	ORTHO	Hyperbaric Bupivacaine 0.5% 7.5 mg ($n = 25$) Hypobaric Bupivacaine 0.18% 7.5 mg ($n = 25$)	3/35 (8.6) 0/35 (0)	N/A	3/35 (8.6) 0/35 (0)	N/A	Retention defined as inability to initiate micturition – time not indicated
Kaya 2004[38]	RCT	3	50	ORTHO	Hyperbaric Bupivacaine 0.5% 7.5 mg ($n = 25$) Hypobaric Bupivacaine 0.18% 7.5 mg ($n = 25$)	0/25 (0) 0/25 (0)	N/A	N/A	N/A	Retention not defined
Borghi 2003[29]	RCT	5	90	ORTHO	Hyperbaric Bupivacaine 0.5% 1. 4 mg ($n = 30$) 2. 6 mg ($n = 30$) 3. 8 mg ($n = 30$)	 1. 0/30 (0) 2. 0/30 (0) 3. 0/30 (0)	N/A	 1. 0/30 (0) 2. 0/30 (0) 3. 0/30 (0)	N/A	Retention not defined
Sungurtekin 2003[58]	RCT	3	60	GEN	Hyperbaric Bupivacaine 0.5% 7.5 mg ($n = 30$)	2/30 (6.7)	N/A	N/A	N/A	Retention not defined Compared to local infiltration, no difference
Voelckel 2009[62]	RCT	3	40	ORTHO	Hyperbaric Bupivacaine 0.5% 5 mg	13/20 (65.0)	N/A	9/20 (45.0)	N/A	Retention defined as bladder volume > 500 mL by US and inability to initiate micturition

Table 3 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Faas 2002[33]	REV	N/A	113	GEN	1. Lidocaine 5% dose N/A ($n = 77$) 2. Bupivacaine 0.75% dose N/A ($n = 19$) 3. Procaine 10% dose N/A ($n = 16$) 4. Tetracaine 1% dose N/A ($n = 1$)	*7/113 (6.2)	N/A	*7/113 (6.2)	N/A	Retention defined as requiring catheterization No criteria for catheterization defined *Results were reported as combined totals and not differentiated between drug/dose
Mulroy 2002[49]	RCT	3	110	AMB	1. Procaine 85 mg ($n = 67$) 2. Lidocaine 60 mg ($n = 28$) 3. Bupivacaine 6 mg ($n = 15$)	1. 0/67 (0) 2. 0/28 (0) 3. 0/15 (0)	N/A	3/201* (1.5)	N/A	Retention defined as bladder volume > 400 mL by US and unable to initiate micturition in PACU * Study did not differentiate between 110 undergoing spinal and 91 undergoing epidural block
Kuusniemi 2000[20]	RCT	3	60	ORTHO	1. Isobaric Bupivacaine 0.5% 2. 6 mg ($n = 30$) 3. Hyperbaric Bupivacaine 0.5% 6 mg ($n = 30$)	1. 0/30 (0) 2. 0/30 (0)	N/A	N/A	N/A	Retention not defined
Keita 2005[39]	OBS	N/A	42	GEN ORTHO URO	Bupivacaine 0.5% dose N/A	7/42 (16.7)	N/A	7/42 (16.7)	N/A	Retention defined as bladder volume > 600 mL and unable to initiate micturition
Lamonerie 2004[41]	OBS	N/A	19	ORTHO GEN	Bupivacaine 0.5% dose N/A	11/19 (57.9)	N/A	11/19 (57.9)	N/A	Retention defined as bladder volume > 500 mL and inability to micturate after 30 min
Pavlin 1998[50]	OBS	N/A	84	AMB	1. Bupivacaine dose N/A ($n = 54$) 2. Lidocaine dose N/A ($n = 31$)	1. 16/107* (15.0)	N/A	N/A	N/A	Retention defined as inability to void *No differentiation between types of local anesthetic and spinal *vs* epidural

Table 3 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Petros 1990[52]	REV	N/A	111	GEN	1. Bupivacaine 0.5% dose N/A ($n = 58$)	1. 26/59 (44.1)	N/A	1. 26/59 (44.1)	N/A	Retention defined as catheterization volume > 400 mL
					2. Lidocaine 5% dose N/A ($n = 52$)	2. 10/52 (19.2)		2. 10/52 (19.2)		Catheterization when bladder palpable with patient urge
Schmittner 2010[56]	RCT	1	201	GEN	Hyperbaric Bupivacaine 0.5%	N/A	N/A	N/A	N/A	No difference between spinal *vs* TIVA. Time to micturition:
					5 mg ($n = 101$)					Spinal – 237 min, TIVA – 230 min
Prilocaine										
Kreutziger 2010[40]	OBS	N/A	86	ORTHO	Prilocaine 2% 60 mg	20/86 (23.3)	123	20/86 (23.3)	0/86 (0)	Retention defined as bladder volume > 600 mL and inability to initiate micturition
Hendriks 2009[17]	RCT	4	72	ORTHO	1. Prilocaine 2% 50 mg ($n = 36$)	N/A	N/A	1. 3/36 (8.3)	N/A	In favour of Articaine ($P < 0.001$)
					2. Articaine 2% 50 mg ($n = 36$)			2. 1/36 (2.8)		Criteria for catheterization not defined
Lidocaine										
Breebaart 2003[13]	RCT	5	90	ORTHO	1. Isobaric Lidocaine 2% 60 mg ($n = 30$)	1. 0/30 (0)	N/A	1. 0/30 (0)	N/A	Retention defined as bladder volume > 500 mL and unable to void, sensation but unable to initiate micturition, or PVR of > 300 mL
					2. Isobaric L-bupivacaine 0.33% 10 mg ($n = 30$)	2. 1/30 (3.3)		2. 1/30 (3.3)		
					3. Isobaric Ropi 0.5% 10 mg ($n = 30$)	3. 1/30 (3.3)		3. 1/30 (3.3)		
Urmey 1997[60]	RCT	5	40	ORTHO	Isobaric Lidocaine 2% 60 mg ($n = 40$)	0/40 (0)	N/A	0/40	N/A	Retention defined as inability to void
										*RCT between different needle aperture directions
Urmey 1995[22]	RCT	3	90	ORTHO	Isobaric Lidocaine 2%		N/A	N/A	N/A	Retention defined as inability to void prior to discharge
					1. 40 mg ($n = 29$)	1. 0/29 (0)				
					2. 60 mg ($n = 32$)	2. 0/32 (0)				
					3. 80 mg ($n = 29$)	3. 0/29 (0)				

Table 3 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Toyonaga 2006[59]	REV	N/A	2011	GEN	Lidocaine 3% dose N/A	336/2,011 (16.7)	N/A	336/ 2,011 (16.7)	N/A	Retention defined as inability to void and requiring catheterization > 24 hr postoperatively 1,442 received epidural eptazocine
Petros 1991[53]	REV	N/A	145	GEN	Lidocaine 5% dose N/A	12/145 (13.8)	N/A	12/145 (13.8)	N/A	Retention defined as catheterization volume > 400 mL Catheterization when bladder palpable with patient urge
Linares-Gil 2009[42]	OBS	N/A	406	GEN ($n = 219$) ORTHO (n = 187)	3% Hyperbaric Lidocaine 0.9 $mg \cdot kg^{-1}$	N/A	N/A	0/406 (0)	N/A	Criteria for catheterization not indicated
Mepivacaine										
Pawlowski 2000[51]	RCT	5	60	ORTHO	1. Isobaric Mepiv 1.5% 60 mg ($n = 29$)	0/29 (0)	N/A	N/A	N/A	Retention not defined
					2. Isobaric Mepiv 2% 80 mg ($n = 31$)	0/31 (0)				
Local anesthetic with long-acting opioid (85 patients)										
Zacharoulis 2009[64]	OBS	N/A	45	GEN	Hyperbaric Bupivacaine 0.5% 15 mg, morphine 250 µg, fent 20 µg	16/45 (35.6)	N/A	16/45 (35.6)	1/16 (6.3)	Retention not defined
Mahan 1993[45]	REV	N/A	40	ORTHO	Hyperbaric Tetracaine 5-8 mg + morphine 0.2-0.4 mg ($n = 40$)	10/40 (25.0)	N/A	10/40 (25.0)	N/A	Retention defined as volume 400-600 mL and inability to void despite urge, distended bladder, unable to void after bethanecol, and requiring catheterization
Local anesthetic with short-acting opioid (381 patients)										
McLain 2005[46]	OBS	N/A	200	ORTHO	Isobaric Bupivacaine 0.5% 15 mg, fent 2 µg, epi 200 µg	16/200 (8.0)	N/A	N/A	N/A	Retention not defined No difference compared with general anesthesia

Table 3 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Intrathecal Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Song 2000[57]	RCT	3	25	GEN	Hyperbaric Bupivacaine 0.75% 9-11.25 mg + fent 25 μg	5/25 (20.0)	N/A	N/A	N/A	Retention not defined
van Veen 2008[61]	RCT	3	100	GEN	Hyperbaric Bupivacaine 0.5%, sufent dose N/A ($n = 49$)	13/49 (75.5)	N/A	13/49 (26.5)	0/13 (0)	Local infiltration *vs* intrathecal Bladder volume assessed by US 3 hr postoperatively Volume to define retention N/A
Gupta 2003[16]	RCT	5	40	GEN	Fent 25 μg with Hyperbaric Bupivacaine 0.5% 6 mg ($n = 20$)	3/20 (15.0)	N/A	3/20 (15.0)	N/A	Retention defined as bladder volume > 500 mL and unable to void requiring catheterization
					Hyperbaric Bupivacaine 0.5% 7.5 mg ($n = 20$)	4/20 (20.0)		4/20 (20.0)		No significant difference between groups
Mulroy 2000[48]	RCT	3	16	ORTHO	Procaine 75 mg + fent 20 μg	0/16 (0)	N/A	N/A	N/A	Retention defined as inability to void
Undefined (420 patients)										
Lingaraj 2007[43]	REV	N/A	23	ORTHO	N/A	0/23 (0)	N/A	N/A	N/A	Retention not defined
Sarasin 2006[55]	OBS	N/A	182	ORTHO	N/A	94/182 (51.6)	N/A	94/ 182 (51.6)	N/A	Retention defined as bladder volume > 500 mL by US
Bodker 2003[28]	OBS	N/A	16	GYN	N/A	1/16 (6.3)	N/A	1/16 (6.3)	0/16	Retention defined as postoperative bladder volume by US exceeding preoperative volume and unable to initiate micturition
Zaheer 1998[65]	REV	N/A	78	GEN	N/A	28/78 (35.9)	N/A	28/78 (35.9)	N/A	Retention defined as requiring catheterization within 24 hr
Fleischer 1994[36]	OBS	N/A	28	GEN	N/A	9/28 (32.1)	N/A	N/A	N/A	Retention not defined
Young 1987[63]	REV	N/A	93	GEN	N/A	17/93 (18.2)	N/A	N/A	6/93 (6.5)	Retention not defined

AMB = ambulatory; fent = fentanyl; epi = epinephrine; GEN = general surgery; FEM/SCI = femoral/sciatic; GYN = gynecology; morph = morphine; N = number in group; n = number in study; N/A = not applicable or not indicated in study; NS = normal saline; OBS = observational study; ORTHO = orthopedic; PACU = postanesthesia care unit; PVR = post void residual; RCT = randomized controlled trial; REV = retrospective review; ropi = ropivacaine; sufent = sufentanil; TIVA = total intravenous anesthetic; URO = urology; US = ultrasound

Table 4 - Epidural anesthesia or analgesia studies

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Total 4,938 patients										
Local Anesthetic only (672 patients)										
Bupivacaine										
Matthews 1989[86]	OBS	N/A	9	THOR	Bupivacaine 0.25% 5 mL·hr^{-1}	6/9 (66.7)	N/A	6/9 (66.7)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Singelyn 2005[95]	RCT	3	15	ORTHO	Bupivacaine 0.125% 10 mL·hr^{-1}	6/15 (40.0)	N/A	N/A	N/A	Retention defined as requiring catheterization
Lanz 1982[84]	RCT	5	117	ORTHO	1 Mepivacaine 2% ($n = 72$) 2 Bupivacaine 0.5% ($n = 45$)	19/117 (16.2)	N/A	19/117 (16.2)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Ryan 1984[54]	REV	N/A	81	GEN	1 Bupivacaine, dose N/A ($n = 32$) 2 Lidocaine, dose N/A ($n = 21$) 3 Mepivacaine, dose N/A ($n = 12$) 4 2-Chloroprocaine, dose N/A ($n = 14$) 5 Prilocaine, dose N/A ($n = 2$)	10/81 (12.3)	N/A	9/81 (11.1)	N/A	Retention defined as requiring catheterization Unclear as to which local anesthetic resulted in retention Criteria for catheterization not defined
Ropivacaine										
Farag 2005[35]	RCT	1	16	ORTHO	Ropivacaine 1% 15 mL	0/16 (0)	N/A	N/A	N/A	Retention not defined Compared with intrathecal bupivacaine
Ladak 2009[83]	OBS	N/A	5	THOR	Ropivacaine 0.2%	0/5 (0)	N/A	N/A	N/A	Thoracic epidural Retention defined as US bladder volume > 600 mL or by inability to void
Evron 2006[75]	RCT	5	100	OB	Ropivacaine 0.2% 5 mL·hr^{-1}, PCEA 5 mL	1/100 (1.0)	N/A	1/100 (1.0)	10/100 (10.0)	Retention defined as bladder volume > 300 mL by US Numbers reported are postpartum after epidural removal 33% of patients catheterized during labour Criteria for catheterization not defined

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Turner 1996[97]	RCT	2	115	ORTHO	Ropivacaine 0.2%	2/22 (9.1)	N/A	N/A	N/A	Retention not defined
					6 $mL \cdot hr^{-1}$ ($n = 22$)	1/22 (4.7)				
					8 $mL \cdot hr^{-1}$ ($n = 23$)	2/22 (9.1)				
					10 $mL \cdot hr^{-1}$ ($n = 23$)	5/24 (20.8)				
					12 $mL \cdot hr^{-1}$ ($n = 24$)	7/24 (29.2)				
					14 $mL \cdot hr^{-1}$ ($n = 23$)					
Prilocaine										
Gurel 1986[78]	OBS	N/A	35	GEN	Prilocaine 2% 400 mg ($n = 35$)	11/35 (31.4)	N/A	6/35 (17.1)	N/A	Retention defined as being unable to void within 12 hr of epidural
Reiz 1980[92]	RCT	3	18	ORTHO	Prilocaine 2% + epi 5 $\mu g \cdot mL^{-1}$ ($n = 18$)	0/18 (0)	N/A	N/A	N/A	Retention not defined
Lidocaine										
Faas 2002[33]	REV	N/A	31	GEN	Lidocaine 2% + epi, dose N/A	1/31 (3.2)	N/A	1/31 (3.2)	N/A	Retention defined as requiring catheterization
					2-Chloroprocaine 3%, dose N/A					Criteria for catheterization not defined
Mulroy 2002[49]	RCT	3	91	AMB	2-Chloroprocaine 2% – 21 mL ($n = 43$)	0/91 (0)	N/A	0/91 (0)	N/A	See Table 1 for comments
					Lidocaine 2% – 19 mL ($n = 48$)					Criteria for catheterization not defined
Pavlin 1998[50]	OBS	N/A	23	AMB	Lidocaine, dose N/A	16/107* (15.0)	N/A	N/A	N/A	Retention defined as inability to void
										*No differentiation between types of local anesthetic and spinal *vs* epidural
2-Chloroprocaine										
Mulroy 2000[48]	RCT	3	16	ORTHO	2-Chloroprocaine 3% 450 mg	0/16 (0)	N/A	0/16 (0)	N/A	Retention defined as inability to void
										Criteria for catheterization not defined
Local anesthetic with long-acting opioid (555 patients)										
Bupivacaine										
Evron 1985[76]	OBS	N/A	80	OB	Bupivacaine 0.5% 20 mL	20/40 (50.0)	N/A	1. 23/40 (57.5)	1. 4/40 (10.0)	Retention not defined
					1. Morphine 4 mg ($n = 40$)	1/40 (2.5)		2. 1/40 (2.5)	2. 0/40 (0)	Criteria for catheterization not defined
					2. Methadone 4 mg ($n = 40$)					

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Lanz 1982[84]	RCT	5	57	ORTHO	1 Mepivacaine 2% + morph 0.1 mg·kg^{-1} ($n = 35$) 2. Bupivacaine 0.5% + morph 0.1 mg·kg^{-1} ($n = 22$)	22/57 (38.6)	N/A	22/57 (38.6)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Bigler 1989[70]	RCT	3	10	GEN	Bupivacaine 0.5% + morph 20 μg·mL^{-1}, 5 mL·hr^{-1}	1/10 (10.0)	N/A	1/10 (10.0)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Basse 2000[69]	OBS	N/A	98	GEN	Bupivacaine 0.25% + morph 50 μg, 4 mL·hr^{-1}	9/98 (9.2)	N/A	9/98 (9.2)	4/98 (4.1)	Retention defined as requiring re-insertion of catheter after trial of void on postoperative day 2
Ladak 2009[83]	OBS	N/A	44	THOR	Bupivacaine 0.1% + hydromorph 15 μg·mL^{-1}	5/44 (11.4)	N/A	N/A	N/A	Thoracic epidural Retention defined as US bladder volume > 600 mL or by inability to void
Gedney 1998[77]	RCT	3	160	ORTHO	Bupivacaine 0.0625% + 1. Diamorph 50 μg·mL^{-1} 2. Morph 50 μg·mL^{-1} 3. Fent 2 μg·mL^{-1} 4. Meth 100 μg·mL^{-1} 5. Pethidine 1 mg·mL^{-1} Bupivacaine 0.125% + 6. Diamorph 50 μg·mL^{-1} 7. Morph 50 μg·mL^{-1} 8. Fent 2 μg·mL^{-1} 9. Meth 100 μg·mL^{-1} 10. Pethidine 1 mg·mL^{-1} 16 patients per group 6-8 mL·hr^{-1} x 48 hr	52/98 (53.1)	N/A	52/98 (53.1)	N/A	Retention defined as requiring catheterization 62 patients catheterized preoperatively and maintained throughout epidural infusion not included in calculation Criteria for catheterization not defined
Ropivacaine										
Kim 2006[82]	RCT	5	30	GEN	Ropivacaine 0.2% + morph 36 μg·mL^{-1} 5 mL·hr^{-1}, PCEA 0.5 mL	13/30 (43.3)	N/A	1/30 (3.3)	N/A	Retention defined as serious major problems according to scale described by Vercauteren[98]
Prilocaine										
Gurel 1986[78]	OBS	N/A	44	GEN	Prilocaine 2% 400 mg + morph 3 mg ($n = 44$)	35/44 (79.5)	N/A	12/44 (27.3)	N/A	Retention defined as being unable to void within 12 hr of epidural

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Reiz 1980[92]	RCT	3	15	ORTHO	Prilocaine 2% + epi 5 μg·mL^{-1} + postoperative Morphine (mean 3.6 mg)	2/15 (13.3)	N/A	N/A	N/A	Retention not defined
Lidocaine										
Capdevila 1999[72]	RCT	2	17	ORTHO	Lidocaine 1% + morph 30 μg·mL^{-1} + clonidine 2 μg·mL^{-1}, 0.1 mL·kg^{-1}	9/17 (52.9)	N/A	9/17 (52.9)	N/A	Retention defined as inability to void despite urge
Local anesthetic with short-acting opioid (1,579 patients)										
Bupivacaine										
Oloffson 1997[88]	RCT	3	1,000	OB	Bupivacaine 0.25% + sufent 5 μg·mL^{-1} ($n = 500$), 6 mL bolus Bupivacaine 0.125% + sufent 10 μg ($n = 500$) 6 mL bolus	17/500 (3.4) 10/500 (2.0)	N/A	17/500 (3.4) 10/500 (2.0)	N/A	Retention defined as inability to void with bladder volume > 500 mL
Turker 2003[96]	RCT	2	30	ORTHO	Bupivacaine 0.125% + fent 2 μg·mL^{-1}, 10 mL·hr^{-1}	7/30 (23.3)	N/A	N/A	N/A	Retention not defined
Singelyn 1998[94]	OBS	N/A	64	ORTHO	Bupivacaine 0.125% + sufent 0.1 μg·mL^{-1} + clonidine 1 μg·mL^{-1}, 5-7 mL·hr^{-1}, PCEA 2.5 mL	21/64 (32.8)	N/A	N/A	N/A	Retention not defined
Vercauteren 1998[98]	RCT	5	60	ORTHO	Sufent 0.1 μg·mL^{-1} epidural 3 mL·hr^{-1}, PCEA 3 mL 1. Bupivacaine 0.12% ($n = 20$) 2. Bupivacaine 0.06% ($n = 20$) 3. No Bupivacaine ($n = 20$)	8/20 (40.0) 2/20 (10.0) 3/20 (15.0)	N/A	8/20 (40.0) 2/20 (10.0) 3/20 (15.0)	N/A	Retention defined as requiring catheterization Catheterization performed with 1. Incontinence 2. Inability to urinate > 18 hr postoperatively or 6 hr from previous void 3. Severe urge, but cannot initiate 4. Inability to void > 200 mL
Wuethrich 2010[100]	OBS	N/A	13	URO	Bupivacaine 0.1% + fent 2 μg·mL^{-1} + epi 2 μg·mL^{-1} – 8 mL·hr^{-1}, PCEA 5 mL	N/A	425	13/13 (100.0)	0/13 (0)	Thoracic epidural PVR returned to normal after epidural discontinued
Chu 2006[74]	RCT	1	60	ORTHO	Bupivacaine 0.1% + fent 2 μg·mL^{-1}, rate N/A	8/30 (26.7)	N/A	N/A	N/A	Retention not defined

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Carli 2002[73]	RCT	2	32	GEN	Bupivacaine 0.1% + fent 2 $\mu g \cdot mL^{-1}$, 8-15 $mL \cdot hr^{-1}$	2/32 (6.3)	N/A	2/32 (6.3)	0/32	Retention defined as requiring catheterization for inability to void
Paulsen 2001[89]	RCT	2	23	GEN	Bupivacaine 0.1% + fent 5 $\mu g \cdot mL^{-1}$, 8-10 $mL \cdot hr^{-1}$	3/23 (13.4)	N/A	3/23 (13.4)	3/23	Retention not defined Criteria for catheterization not defined
Senagore 2003[93]	RCT	3	18	GEN	Bupivacaine 0.1% + fent 20 $\mu g \cdot mL^{-1}$, 4-6 $mL \cdot hr^{-1}$	1/18 (5.6)	N/A	N/A	N/A	Retention not defined
Ropivacaine										
Niemi 2002[87]	RCT	5	12	GEN	Ropivacaine 0.1% + fent 2 $\mu g \cdot mL^{-1}$ + epi 2 $\mu g \cdot mL^{-1}$	4/12 (33.3)	N/A	4/12 (33.3)	N/A	Retention not defined Indication for catheterization not defined
Liang 2010[85]	OBS	N/A	60	OB	Ropivacaine 0.067% + fent 2.5 $\mu g \cdot mL^{-1}$ – 5 $mL \cdot hr^{-1}$, PCEA 4 mL	9/60 (15.0)	N/A	4/60 (6.7)	N/A	Retention defined as PVR > 150 mL or bladder volume > 500 mL by US and unable to void
Evron 2006[75]	RCT	5	98	OB	Ropivacaine 0.2% + fent 2 $\mu g \cdot mL^{-1}$ – 5 $mL \cdot hr^{-1}$, PCEA 5 mL	4/98 (4.1)	N/A	4/98 (4.1)	7/98 (7.1)	Retention defined as bladder volume > 300 mL by US Numbers reported are postpartum after epidural removal 33% of patients in each group catheterized during labour Criteria for catheterization not defined
Kim 2006[82]	RCT	5	30	GEN	Ropivacaine 0.2% + sufent 0.9 $\mu g \cdot mL^{-1}$ 5 $mL \cdot hr^{-1}$, PCEA 0.5 mL	0/30 (0)	N/A	0/30 (0)	N/A	Retention defined as serious major problems according to scale described by Vercauteren[87]
Borghi 2004[71]	RCT	1	48	ORTHO	Ropivacaine 0.2% + sufent 0.25 $\mu g \cdot mL^{-1}$ 4 $mL \cdot hr^{-1}$, PCEA 5 mL	N/A	N/A	29/48 (60.4)	N/A	Indication for catheterization not defined
Lidocaine										
Kau 2003[81]	RCT	3	31	GEN	Lidocaine 30 mg + fent 20 μg	0/31 (0)	N/A	0/31 (0)	N/A	Retention not defined Criteria for catheterization not defined

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Opioid only (1,552 patients)										
Morphine										
Petersen 1982[90]	OBS	N/A	32	GEN	Morphine 25.9-32.3 mg	14/32 (44.8)	N/A	14/32 (44.8)	N/A	Retention defined as sensation of requiring voiding but unable to initiate
Husted 1985[80]	OBS	N/A	12	GYN	Morphine 4 mg q 20 min, mean 27.9 mg	2/12 (16.7)	N/A	N/A	N/A	Retention not defined
Viscusi 2005[99]	RCT	5	183	ORTHO	Extended release morphine 15 mg ($n = 47$) 20 mg ($n = 45$) 25 mg ($n = 43$)	1/136 (0.7)	N/A	N/A	N/A	Retention not defined
Reiz 1980[91]	REV	N/A	1,200	N/A	Morphine 2 mg	181/1,200 (15.1)	N/A	N/A	N/A	Retention not defined
Liang 2010[85]	OBS	N/A	60	OB	Morphine 1.5 mg ($n = 60$)	20/60 (33.3)	N/A	13/60 (21.7)	N/A	Retention defined as PVR > 150 mL or bladder volume > 500 mL by US and unable to void
Gustaffson 1982[79]	RCT	3	10	ORTHO	Morphine 0.05 mg·kg^{-1}	2/10 (20.0)	N/A	2/10 (20.0)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Fentanyl										
Baron 1996[67]	RCT	5	34	THOR	Infusion 0.5 μg·kg^{-1}·hr^{-1} Fent 5 μg·mL^{-1}($n = 16$) Fent 5 μg·mL^{-1} + epi 3.3 μg·mL^{-1} ($n = 18$)	8/16 (50.0) 10/18 (55.6)	N/A	8/16 (50.0) 10/18 (55.6)	N/A	Retention defined as requiring catheterization Criteria for catheterization not defined
Ahuja 1985[66]	OBS	N/A	21	GEN THOR	Fent 0.5-1 μg·kg^{-1}·hr^{-1}	0/21 (0)	N/A	0/21 (0)	0/21	Retention not defined Criteria for catheterization not defined
Undefined (580 patients)										
Barretto 2007[68]	OBS	N/A	487	ORTHO THOR	N/A	115/487 (23.6)	N/A	115/487 (23.6)	N/A	Retention defined as inability to void spontaneously
Lingaraj 2007[43]	REV	N/A	26	ORTHO	N/A	6/26 (23.1)	N/A	6/26 (23.1)	N/A	Retention defined as unable to void spontaneously and requiring catheterization Criteria for catheterization not defined

Table 4 continued

Author/Year	Study Design	Jadad Score	N	Surgical Class	Epidural Drug/Dose	Incidence of Retention (%)	PVR (mL)	Catheterization (%)	Infection (%)	Comments
Bodker 2003[28]	OBS	N/A	67	GYN	N/A	9/67 (13.4)	N/A	9/67 (13.4)	0/67 (0)	Retention defined as bladder volume by US exceeding pre-op bladder capacity estimate and inability to void

AMB = ambulatory, Diamorph = diamorphine, epi = epinephrine, Fent = fentanyl, GEN = general surgery, GYN = gynecology, hydromorph = hydromorphone; Meth = methadone, morph = morphine, *n* = number in group, N = number in study, N/A = not applicable or not indicated in study, OB = obstetric, OBS = observational study, ORTHO = orthopedic surgery, PCEA = patient controlled epidural analgesia, PVR = post void residual, RCT = randomized controlled trial, REV = retrospective review, Sufent = sufentanil, THOR = thoracic surgery, URO = urology, US = ultrasound

intravesical pressures of 40-50 cm H_2O) did not occur until the block regressed to the S3 segment. Importantly, the mean duration of detrusor block was significantly longer than somatic motor blockade; 233 min *vs* 144 min, respectively, for plain lidocaine; 332 min *vs* 124 min, respectively, for lidocaine with sufentanil; and 462 min *vs* 233 min, respectively, for hyperbaric bupivacaine.

Kuipers *et al.* studied the dose effect behaviour of isolated intrathecal opiates (sufentanil or morphine) on detrusor function in 40 healthy male volunteers randomized to receive sufentanil (10 or 20 μg) or morphine (0.1 or 0.3 mg).[9] Urodynamic data, including flow rates, bladder pressures, and post void residuals, were recorded hourly. Typically, administration of opiates resulted in dose-dependent decreases in urinary flow rate, increased voiding time, increased post void residual, and diminished urge sensation. Bladder function reverted to normal within 24 hr in all those receiving sufentanil and morphine 0.1 mg. Two participants receiving the higher morphine dose (0.3 mg) did not have full recovery of bladder function within the 24-hr study period. The lower dose of sufentanil (10 μg) resulted in diminished urge (itself a subjective sensation) in six of ten subjects *vs* nine of ten when the larger dose was used.

The above urodynamic data show the mechanism of detrusor dysfunction, and our data suggest that it is drug and dose related. It is unclear when detrusor dysfunction becomes POUR, although, regardless of the definitions used by source studies, POUR occurred more frequently with high potency local anesthetics, higher doses, and opioids.

There are other purported risk factors for POUR that were not addressed in this review, including the volume of intraoperative fluid administered, type of surgery, and age. Keita *et al.* prospectively studied 313 adult patients (mean age 46 yr; range 16-88 yr) scheduled for general (86.5%) or neuraxial (13.5%) anesthesia and showed that the volume of intraoperative fluid administration ($\geq$ 750 mL odds ratio [OR] = 2.3), age ($\geq$ 50 yr OR = 2.4), and bladder volume on entry to the postanesthesia care unit ($\geq$ 270 mL OR = 4.8) were independent risk factors for the development of POUR.[39] Joelsson-Alm *et al.* observed that orthopedic surgical patients were 6.87 times (95% confidence interval [CI] 1.76 to 26.79) more likely to develop bladder distension.[101] Other studies have implicated colorectal surgery and obstetric status as risk factors. The odds ratio for POUR after colorectal surgery and epidural analgesia was reported to be as great as 4.3 (95% CI 1.2 to 15.9).[5] Weiniger *et al.* showed that intrapartum women receiving epidural analgesia during labour had greater post void residuals independent of fluid volume administered when compared with controls not receiving epidural anesthesia (median 240 mL *vs* 45 mL, respectively) with

no significant difference on postpartum days one or two.[102] In addition, advanced age appears to be a risk factor for urinary retention as males > 70 yr having spinal anesthesia for lower limb joint replacement are at higher risk of developing retention than females or those < 69 yr irrespective of anesthetic modality.[55,103]

Conclusion

Our review of the literature suggests that the duration of detrusor dysfunction caused by neuraxial anesthesia and analgesia is related to the dose/potency of local anesthetic and the use of long-acting neuraxial opioids. This may influence the incidence of POUR. Unfortunately, the defining criteria in the literature are so heterogeneous when present that an accurate estimate of the incidence and subsequent complications is extremely difficult to determine.

There are several limitations to our review. First, only two of the RCTs included in this review specifically compared general with neuraxial anesthesia and the respective incidence of POUR as a primary outcome, inherently resulting in underpowered results. The observational studies included frequently lacked a comparator group. Second, the definitions of POUR were widely variable such that POUR in one study may not be considered POUR in another. Details regarding individual cases were not provided, preventing any ability to rate outcomes according to standardized criteria.

From the available literature, short-acting neuraxial blockade is safe in both inpatient and ambulatory anesthesia given the short duration of detrusor dysfunction with a minimal incidence of POUR and subsequent catheterization/infection. However, clinicians should select agents carefully to strike a balance between duration of somatic blockade and the risk of POUR. We suggest that clinicians remain cognizant of this issue and scan patients at higher risk of urinary retention with catheterization at a bladder volume of 500 mL (~cystometric capacity) given that there is a lack of knowledge regarding the subclinical implications of an episode of retention that "spontaneously" resolves.

Moving forward, standard definitions for urinary retention and indications for catheterization should be developed in conjunction with urologists so that relevant clinical trials comparing anesthetic modalities and incorporating urological endpoints produce data that can be easily used by all clinicians to assess and manage this clinical problem.

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