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Postoperative Urinary Retention

Anesthetic and Perioperative Considerations

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Urinary retention is common after anesthesia and surgery, reported incidence of between 5% and 70%. Comorbidities, type of surgery, and type of anesthesia influence the development of postoperative urinary retention (POUR). The authors review the overall incidence and mechanisms of POUR associated with surgery, anesthesia and analgesia. Ultrasound has been shown to provide an accurate assessment of urinary bladder volume and a guide to the management of POUR. Recommendations for urinary catheterization in the perioperative setting vary widely, influenced by many factors, including surgical factors, type of anesthesia, comorbidities, local policies, and personal preferences. Inappropriate management of POUR may be responsible for bladder overdistension, urinary tract infection, and catheter-related complications. An evidence-based approach to prevention and management of POUR during the perioperative period is proposed.

BLADDER catheterization is a common procedure during inpatient major surgery that allows monitoring of urine output, guides volume resuscitation, and serves as a surrogate marker of hemodynamic stability. With an increase in outpatient and fast-track surgical procedures, perurethral catheterization is restricted to fewer procedures and for a limited time. Awareness and identification of patients at risk of developing postoperative urinary retention (POUR) thus assumes greater significance. POUR has been defined as the inability to void in the presence of a full bladder. The widely varying reported incidence of POUR reflects its multifactorial etiology and the lack of uniform defining criteria. This paper reviews the physiology of micturition and analyzes the perioperative factors that contribute to POUR. Evidence-based guidelines for the management of POUR are also provided.

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Mechanism of Micturition

The bladder is composed of a body formed by the detrusor muscle and a funnel-shaped neck. The neck has an internal layer of smooth muscle that surrounds the internal meatus of the bladder—the internal urethral sphincter (IUS). The external urethral sphincter is formed collectively by the overlying striated muscle fibers of the pelvic floor. The adult urinary bladder has a capacity of 400 to 600 ml. The bladder is innervated by efferent somatic, sympathetic, and parasympathetic fibers, whereas the visceral afferent fibers (Aδ and C) arise from the bladder wall (stretch receptors). The parasympathetic fibers cause contraction of the detrusor and relaxation of the neck, permitting micturition. The sympathetic fibers, in contrast, influence the relaxation of the detrusor and close the internal urethral sphincter. These two systems are governed by spinal reflexes, which are regulated by two pontine brainstem centers, the Pontine Storage Centre and the Pontine Micturition Centre. The voluntary control of the bladder becomes fully developed by the first few years of life and involves the coordination among the frontal cortex, the pontine centers, and the spinal segments influencing bladder control. During micturition, two phases can be distinguished, the storage phase and the emptying phase.

The high compliant bladder allows for storage of a large volume of urine without an increase in the intravesical pressure. The first urge to void is felt at a bladder volume of 150 ml. The tension receptors in the bladder wall are activated at a volume of approximately 300 ml, creating the sense of fullness. The activation of the tension receptors propagates signals through Aδ and C fibers that travel through the pelvic sensory nerves, arriving at the spinal cord, where they activate parasympathetic neurons. Activation of the parasympathetic neuron stimulates efferent pelvic nerves that lead to contraction of the detrusor muscle. Detrusor contractions last only a few seconds, substantially raising the intravesical pressure from a resting pressure of 40 mm H_2O to a few hundred mm H_2O. When the intravesical pressure reaches the voiding threshold, the detrusor contractions increase in intensity, frequency, and duration. This creates a complete and synchronous contraction of the

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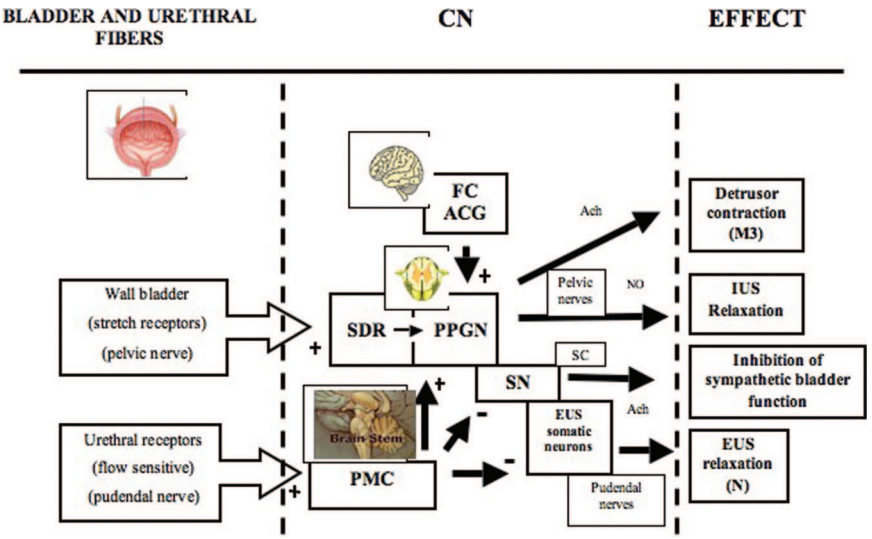

Fig. 1. Emptying phase anatomical pathways and reflexes. + = stimulation; – = inhibition; EUS = external urethral sphincter; FC = frontal cortex; IUS = internal urethral sphincter; M3 = muscarinic receptor type 3; NO = nitric oxide; PPGN = parasympathetic preganglionic neurons; PPRG = parasympathetic preganglionic neurons; SC = spinal cord; SDR = sacral dorsal roots; SN = sympathetic neurons (T-L segments).

detrusor muscle, allowing the bladder to empty quickly and efficiently. If micturition is not desired or is inconvenient, afferent stimuli from the stretch receptors of the bladder along with the proprioceptive afferents of the urethra, penis, vagina, rectum perineum, and anal sphincters activate the sympathetic system and external urethral sphincter motor neurons and simultaneously inhibit the parasympathetic system. The final effect is to prevent micturition through the contraction of the sphincters and the relaxation of detrusor muscle. Furthermore cerebral input from the frontal cortex and the pontine centers also aids in inhibiting the parasympathetic neurons and activating the sympathetic pathways. A schematic illustration of the anatomical structures and reflexes involved in the storage phase and emptying phase is summarized in figure 1 and table 1.[1,2]

Diagnosis of POUR

Three methods have been used to diagnose POUR: history and physical examination, the need for bladder catheterization, and, more recently, ultrasonographic assessment (table 2).

Clinical Examination

Pain and discomfort in the lower part of the abdomen have been used as conventional indicators of POUR. However, these symptoms may be masked by regional anesthesia, comorbidities including patients with spinal cord injury or stroke or sedated patients who are unable to effectively communicate their symptoms.[3]

Clinical assessment by palpation and percussion in the suprapubic area is another commonly used method for diagnosis of POUR. This method however lacks the sensitivity to provide an accurate measure of the residual urinary volume. Dullness of the bladder to the level of the umbilicus provides a rough estimate of at least 500 ml of urine, but it can vary as much as 1,000 ml with dullness extending above the umbilicus.[3] Deep palpation of the bladder is not recommended because it can produce significant discomfort and can elicit vagal reflexes evoked by pain. In addition, clinical evaluation has been shown to overestimate the bladder volume compared to ultrasound.[4]

Pavlin *et al.* showed that 61% of day-case surgical patients admitted to the postanesthesia care unit after general anesthesia did not report any symptoms of bladder distension, despite a bladder volume greater than 600 ml as measured by ultrasonography.[5] Similar findings were reported by Stallard *et al.*[6] Lamonerie found that almost a quarter of inpatients evaluated for POUR with ultrasound had overdistended bladder, even in absence of clinical symptoms, and were unable to void at the time of discharge from the recovery room.[7]

Bladder Catheterization

Bladder catheterization is used both as a diagnostic tool and as treatment for POUR. The inability to void in the postoperative period could be multifactorial, including inadequate perioperative fluids. It is imperative to evaluate and treat the underlying cause before making the diagnosis of POUR and proceeding with catheterization. Catheterization is an invasive procedure with the potential to cause complications, including catheter-related infections, urethral trauma, prostatitis, and patient discomfort.[8]

Ultrasound Assessment

Although ultrasound has been used as an imaging modality to evaluate bladder function, its use in the perioperative period as a diagnostic tool for POUR has gained popularity only in the past decade.[9–15] Several studies have shown good correlation between the volumes measured by bladder catheterization and by ultrasound[4,16];

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Table 1. Storage Phase: Anatomical Pathways and Reflexes

Afferent Pathway Afferent Fibers and Nerves	Sopraspinal Centers		SC		Efferent Pathway		
	Voluntary, Control (Cortex)	Pontine Centre	Spinal Integration	Nerve	Efferent, NT	Receptor	Effect
Wall bladder (stretch receptors; hypogastric and pelvic nerves)	—	—	SN (T-L spinal segments)	Hypogastric nerve	NE	α-1 β-2 PG inhibition	IUS contraction Detrusor relaxation Detrusor relaxation; IUS contraction
Proprioceptive urethral/perineal afferents (guarding reflex; pudendal nerve)	—	—	Somatic motoneurons (S spinal segments)	Pudendal nerve	Ach	N	EUS contraction
Penis, vagina, rectum perineum, urethral and anal sphincter somatic afferents (pudendal nerve)	—	—	PPGN SI	—	GABA	GABA R	Detrusor relaxation IUS contraction
EUS contraction (pudendal nerve)		—	PPGN	Pudendal nerve	—	—	Detrusor relaxation IUS contraction
Bladder/urethral pelvic and pudendal afferent	—	PSC	—	SC Somatic motoneurons (S spinal segments)	—	—	Detrusor relaxation IUS contraction
—	FC, ACG	PMC	—	BS	—	—	Detrusor relaxation IUS contraction
				Somatic motoneurons (S spinal segments)	Ach	N	EUS contraction

Ach = acetylcholine; ACG = anterior cingulate gyrus; BS = brainstem; EUS = external urethral sphincter; FC = frontal cortex; GABA = γ-amino-butyric-acid; GABA R = γ-amino-butyric-acid receptor; IUS = internal urethral sphincter; N = nicotine receptor; NE = norephinephrine; NT = neurotransmitter; PG = parasympathetic ganglionic inhibition; PMC = pontine micturition centre; PPGN = parasympathetic preganglionic neurons; PSC = pontine storage centre; S = sacral; SC = spinal cord; SI = spinal interneurons; SN = sympathetic segments; T-L = toraco-lumbar.

in women, however, ultrasound can slightly underestimate bladder volume.[9,16] When ultrasound is performed by the same individual, the difference between urinary volume measured by the ultrasound and by catheterization varies minimally, indicating the need for operator consistency.[15] During laparoscopic cholecystectomy, Greig *et al.* showed that ultrasound monitoring of the bladder before the procedure was more accurate than clinical examination, especially in obese patients and in those with previous lower abdominal surgery.[17] Both the times to void and to discharge from hospital were reduced by using ultrasound in patients considered to be at a high risk of developing POUR.[17] However, this has not been demonstrated in patients considered to be at a low risk of developing POUR.[4] Ultrasound is also useful to monitor bladder volume before it becomes excessively large. Pavlin *et al.* showed that patients at high-risk of POUR can have a postresidual volume greater than 600 ml, even though they were able to void. By identifying these patients at risk of having an overdistended bladder, intravenous fluids can be monitored, and inappropriate early discharge can be avoided.[5]

Perioperative Risk Factors for POUR

Age and Gender

POUR has been shown to increase with age, with the risk increasing by 2.4 times in patients over 50 yr of age.[8,18–22]

A higher incidence of POUR has been reported in men (4.7%) compared to women (2.9%).[8,23] Possible reasons for such age and gender influences include age-related progressive neuronal degeneration leading to bladder

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Table 2. Criteria Used to Define POUR

Clinical Criteria*
Patient discomfort, sensation of a full bladder, palpable, distended bladder[41,48]
Distended bladder[65]
Discomfort caused by a distended, palpable bladder and inability to void[111]
Patient discomfort or palpable bladder, with a volume of urine > 400 ml[18,20,21,50,51,83]
Inability to void with bladder distention[54]
Inability to void urine for > 12 h after induction of anesthesia with > 500 ml urine drained on catheterization[6]
Inability to void[62,66]
Inability to void 8 h after the end of surgery, and the bladder is distended or the patient is uncomfortable[32]
Inability to void in 8 h after removal of Foley catheter[112]
Need of catheterization in 24 h[14,17]
Unable to empty the bladder in 10 h, discomfort, and palpable bladder[24]
Disturbances in micturition as severe/moderate urge to urinate, need of intravenous charbachol[124]
Urinary retention was graded as follows: 0 = none; 1 = mild hesitancy; 2 = straight catheter required; 3 = Foley catheter required[122]
Micturition score[84]
Catheterization in 48 h after the end of the surgery[127]
Parturient unable to void spontaneously and with a residual volume greater than 500 ml (measured by catheterization) were categorized as urinary retention[89]
Need of Bladder Catheterization/Not Specified Criteria
References 26, 27, 29, 59, 67, 68, 81, 86, 87, 90, 94, 105, 107, 110, 108, 114–116, 132, 133, 135–138, 141–143, 145, 147, 153, 166, 183, 184, 187
Ultrasound Assessment*
Inability to void with a bladder volume > 600 ml in 30 h[19]
Inability to void with a bladder volume ≥ 500 ml in 30 h[7]
Residual volume > 500 ml[61]

* When one of these criteria was met, bladder was catheterized.

POUR = postoperative urinary retention.

dysfunction[19] and gender-specific pathologies such as benign prostatic hypertrophy among others.[8,18,20,21]

Type of Surgery

The incidence of POUR varies according to the type of surgery. Although the incidence of POUR in general surgical population is around 3.8%,[8,23] the incidence in joint arthroplasty varies widely (10.7–84%).[24–27] The incidence of POUR after anorectal surgery ranges between 1 and 52%.[22,28–31] Injury to the pelvic nerves and pain evoked reflex increase in the tone of the internal sphincter explains the high incidence of POUR in patients undergoing anorectal surgery.[32–37] After hernia repair, the incidence of POUR ranges between 5.9% and 38%.[18,22,38] POUR has also been reported after gynecological surgery, but with conflicting results. Pavlin found that none of the patients undergoing routine outpatient gynecologic surgery developed POUR, probably because over 90% of these patients had been catheterized during the operation and arrived in postanesthesia care unit with an empty bladder.[5] Previous pelvic surgery can increase the risk of POUR, probably as a result of direct damage to the nerves innervating the lower urinary tract.[8]

Comorbidities

Concurrent neurologic diseases such as stroke, poliomyelitis, cerebral palsy, multiple sclerosis, spinal lesions, and diabetic and alcoholic neuropathy are predisposing factors to the development of urinary retention.[8,31]

Drugs

Medications commonly used in the perioperative period, such as anticholinergic agents, ß-blockers, and sympathomimetics, can interfere with the bladder function.

Administration of muscarinic agonists such as carbachol and bethanecol in animals and humans causes an increase in intravescical pressure, leading to hyperactive detrusor contractions.[39,40] Anticholinergic drugs such as atropine and glycopyrrolate block detrusor contractions and cause bladder hypotonia, also resulting in urinary retention.[8,18]

α_2 agonists and antagonists alter bladder function by acting on the α-receptors of the smooth muscle cells in the upper and lower urinary tracts.[39,41–45] In a randomized double-blind study, Gentili *et al.* studied the effect of intrathecal clonidine, an α_2 agonist, on bladder function and found clonidine caused less POUR when compared to morphine.[44] Although systemic administration of clonidine causes an increase in urethral resistance,[39] its intrathecal injection is devoid of any peripheral effect. Possible mechanisms of clonidine have been proposed including: a decrease in spinal cord sympathetic outflow lowering the tone of IUS,[44] and a supraspinal inhibitory effect on IUS tone and a diuretic effect.[45]

Prazosin, an α_1 antagonist, decreases the peristaltic movements in the ureter, the amplitude of detrusor contractions, the urethral opening pressure, and the frequency of micturition.[42] Stimulation of α_1 receptors by sympathomimetic agents increases the tone of IUS, thus increasing the risk of developing POUR.[8,18]

When ephinephrine is injected intraperitoneally in rats, the intravescical pressure increases without raising urine output, suggesting that ephinephrine increases IUS tone by acting on α receptors in the bladder neck.[39] ß-adrenergic receptors are located in the smooth muscle cells of the detrusor and in minor concentration in the bladder outlet.[46] In animals, stimulation of ß-adrenergic receptors causes relaxation of the detrusor and reduces sphincter tone.[39,46,47] In contrast, ß-adrenergic antagonists may cause urinary retention.[8]

Intravenous Fluids

The amount of intravenous fluids may influence the development of POUR. In patients undergoing hernia repair and anorectal surgery, intravenous administration of more than 750 ml of fluids during the perioperative period increased the risk of POUR by 2.3 times com-

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pared to other surgeries.[8,18,19,28,31,48–50] POUR has not been reported in low-risk surgery and in patients without history of urinary retention.[20,21,51] Excessive infusion of intravenous fluids can lead to overdistension of the bladder,[37] especially in patients under spinal anesthesia whose bladder filling perception is abolished.[52] Overdistension inhibits detrusor function, and the normal micturition reflex cannot be restored even after emptying the urinary bladder with a catheter.[28,50] Therefore, bladder volume greater than 270 ml represents a risk factor for POUR.[19]

Duration of Surgery

Prolonged duration of surgery can cause POUR.[4,53] In patients undergoing ambulatory surgery under central neuraxial technique, the time to void was shown to be directly proportional to the total duration of anesthesia.[53] These findings could be explained by the variation in the volume of intravenous fluids administered during surgery of varying lengths. In fact, Pavlin *et al.* found a significant correlation between bladder volume and the duration of surgery but failed to show a relationship between the bladder volume and the total amount of fluids administered.[4] In contrast, Peterson did not find any causal relationship between the duration of surgery and the risk of POUR.[54]

Effects of Anesthesia and Analgesia

Impact of the Anesthetic and Analgesic Techniques on the Incidence of POUR. In this section, we have examined the evidence from published data with regard to the effects of anesthetic and analgesic techniques on the development of POUR.

A MEDLINE search of clinical trials, published in English, relating to the incidence and the management of POUR was conducted. The computerized search identified key words such as urinary retention, POUR, void dysfunction, micturition dysfunction, opioids and POUR, local anesthetic and POUR, anesthesia and POUR, analgesia and POUR, and surgery and POUR in the title, abstract, and Medical Subject Headings. POUR was defined on the basis of the three methods used in clinical practice, such as clinical examination, the need for bladder catheterization, and ultrasound assessment (table 2). Most of the studies did not specify the criteria to define POUR, reporting only whether it was present or not. The search was amplified to include relevant articles identified by cross-referencing (fig. 2). We included, as selection criteria, clinical trials relating to POUR after cardiothoracic, abdominal, obstetric, gynecologic, and orthopedic surgeries. We excluded articles related to pediatric and urology surgeries, reviews, editorial letters, and case reports. Studies that reported incidence of POUR and those from which it was possible to calculate incidence of POUR were grouped by method of anesthesia and by method of analgesia. The mean percentage

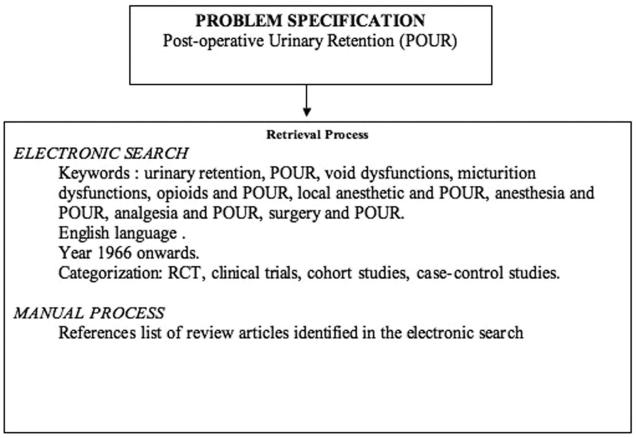

Fig. 2. Search strategy. POUR = postoperative urinary retention; RCT = randomized controlled trials.

reporting the overall incidence of POUR was determined by the method of weighted mean with weighting by the number of subjects in the group. There was considerable variability in the criteria used to define POUR. Variability was minimized by subgrouping the incidence of POUR by the diagnostic method used to define it.[55] When the 95% confidence intervals (CI) fell within the same distribution, the mean incidences of POUR were compared using a chi-square test.

A total of 190 studies were identified as suitable for analysis. There were 86 randomized controlled trials, 21 prospective studies, 23 retrospective studies, 57 clinical and experimental trials, 2 meta-analyses, and 1 review. POUR was the primary outcome in 50 studies and secondary outcome in 58. When patients were grouped by method of anesthesia or analgesia, some studies contributed subjects to more than one group. In 26 studies, 5,268 patients received general anesthesia (table 3), whereas 5,105 patients received intraoperative conduction blockade (spinal, epidural and combined spinal-epidural anesthesia) in 34 studies (table 4). There were 26 studies with a total of 4,870 patients receiving epidural analgesia either as continuous infusion or as single/intermittent bolus or patient-controlled epidural analgesia (table 5), and there were 27 studies with a total of 4,360 patients who received either patient-controlled anesthesia (PCA) or parenteral morphine with or without nonsteroidal antiinflammatory drugs (table 6). In 9 studies, 292 patients received peripheral nerve blocks, (table 7) and 2,141 patients received infiltrations of local anesthetics in 10 studies (table 8). The overall incidence of POUR after general anesthesia was found to be significantly lower in comparison with conduction blockade, whereas the overall incidence of POUR after epidural analgesia was found to be not significantly different in comparison with systemic analgesia (table 9). Similar incidence was found when the criteria to diagnose POUR were unspecified or based on the need for catheterization (table 10). In contrast, when clinical criteria

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Table 3. List of the Studies with the Incidence of POUR after General Anesthesia

Reference	Number of Patients	Type of Surgery	Incidence of POUR (%)	GA
Dobbs *et al.*[153]	95	Abdominal hysterectomy	20	NS
Gonullu *et al.*[38]	577	Abdominal surgery and thyroidectomy	19.2	TPS, N_2O/Halothane
Bailey *et al.*[48]	439	Anorectal surgery	10	NS
Li *et al.*[141]	31	Anorectal surgery	3	Propofol, N_2O/Sevoflurane
Salvati *et al.*[29]	5	Anorectal surgery	40	NS
Petros *et al.*[21]	279	Appendicectomy	24.7	Halothane
Petros *et al.*[20]	360	Cholecystectomy	30.2	Halothane
Zaheer *et al.*[28]	147	Hemorroidectomy	37	NS
Peiper *et al.*[138]	226	Herniorraphy	12.4	NS
Petros *et al.*[18]	150	Herniorraphy	19	Halothane
Sanjay *et al.*[136]	208	Herniorraphy	2.4	NS
Song *et al.*[143]	28	Herniorraphy	0	Propofol, N_2O/Sevoflurane
Young *et al.*[137]	174	Herniorraphy	4	NS
Petros *et al.*[51]	366	Hysterectomy	18	TPS, N_2O/isoflurane
Lingaraj *et al.*[26]	76	Orthopedic surgery	5.3	NS
Brown *et al.*[132]	40	Orthopedic surgery	25	TPS, N_2O/isoflurane
Iorio *et al.*[190]	259	Orthopedic surgery	38	NS
Mulroy *et al.*[81]	16	Orthopedic surgery	0	Propofol c.i./N_2O
Walts *et al.*[183]	187	Orthopedic surgery	24	N_2O/isoflurane or enflurane or halothane or narcotics
Petersen *et al.*[54]	54	Orthopedic surgery	41	NS
Pavlin *et al.*[147]	320	Orthopedic, abdominal, ENT, plastic surgery	1.9	NS
Jellish *et al.*[67]	61	Spine surgery	22.9	N_2O/isoflurane
McLaine *et al.*[68]	200	Spine surgery	23.6	Fentanyl, N_2O/isoflurane
Stallard *et al.*[6]	167	Abdominal surgery, mastectomy, thyroidectomy, varicose vein surgery	14	NS
Zaheer *et al.*[28]	374	Lateral internal, sphincterotomy, fistulotomy, or incision/drainage	6	NS
Keita *et al.*[19]	271	Orthopedic, abdominal, urologic, hernia repair, anal, vascular, and thoracic surgery	14.3	NS
Lamonerie *et al.*[7]	158	Abdominal, thoracic, ENT, vascular, orthopedic surgery	19.6	NS

c.i. = continuous infusion; ENT = eyes, nose, and throat; GA = general anesthesia; N_2O = nitrous oxide; NS= not specified; POUR = postoperative urinary retention; TPS = thiopentone.

were used to define POUR, the incidence after general anesthesia and systemic analgesia were significantly higher then with regional anesthesia and epidural analgesia, respectively ($P < 0.001$ [OR = 1.20] and $P < 0.001$ [OR = 1.76], respectively) (table 10). Such discrepancy can be explained by the fact that most of the studies analyzed were retrospective in nature, with the data obtained from the clinical charts. Furthermore, the clinical criteria used to define POUR differed widely and were often subjective (table 2). Due to the relative paucity of studies using ultrasound assessment, it was not possible to make meaningful comparisons.

Effect of the Anesthetic and Analgesic Techniques on Bladder Function.

General Anesthetic Agents. General anesthetic agents cause bladder atony by interfering with the autonomic nervous system. Studies in rats and dogs have shown that sedative-hypnotic agents and volatile anesthetics suppress micturition reflex.[56,57] Diazepam, pentobarbital, and propofol all decrease detrusor contractions, and isoflurane, methoxyflurane, and halothane suppress detrusor contractions. Halothane also increases bladder capacity.[56] The urodynamic effects caused by volatile anesthetics and sedative-hypnotic agents appear to be caused by inhibition of pontine micturition center and the voluntary control of the cortex on the bladder.[56,57] In a retrospective study by Petros,[20] duration of surgery was found to be significantly associated with POUR, suggesting that urinary retention was more the result of high cumulative doses of halothane administered and not necessarily the length of exposure.

Conduction Blockade.

Spinal Local Anesthetics. Intrathecal local anesthetics act on the neurons of the sacral spinal cord segments (S2–S4) by blocking the transmission of the afferent and efferent action potentials on the nervous fibers from and to the bladder.[52,58] The sensation of urgency to void disappears 30–60 s after intrathecal injection of local anesthetics, but a dull feeling of tension on maximal filling of the bladder persists. Bladder analgesia is due to the block of the transmission of the afferent nerve fibers from the bladder to the micturition center in the brain. The detrusor contraction (detrusor block) is completely abolished 2–5 min after the injection of spinal anesthe-

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Table 4. List of the Studies with the Incidence of POUR after Conduction Blockade

Reference	Number of Patients	Type of Surgery	Incidence of POUR (%)	Conduction Blockade (RA)
Bigler *et al.*[87]	10	Abdominal surgery	10	EA
Evron *et al.*[41]	60	Cesarean section	28.3	EA
Evron *et al.*[111]	120	Cesarean section	22.5	EA
Faas *et al.*[83]	31	Herniorraphy	3	EA
Gurel *et al.*[107]	79	Anorectal surgery	58.2	EA
McLaine *et al.*[68]	200	Spine surgery	8	EA
Reiz *et al.*[94]	33	Orthopedic surgery	9.1	EA
Walts *et al.*[183]	85	Orthopedic surgery	36.4	EA
Bailey *et al.*[48]	40	Anorectal surgery	5	SA
Cataldo *et al.*[32]	49	Anorectal surgery	49	SA
Esmaoglu *et al.*[65]	70	Orthopedic surgery	4.2	SA
Faas *et al.*[83]	113	Herniorraphy	6.2	SA
Fleischer *et al.*[142]	28	Anorectal surgery	32	SA
Gupta *et al.*[61]	40	Herniorraphy	17.5	SA
Imbelloni *et al.*[135]	100	Anorectal	2	SA
Jellish *et al.*[67]	61	Spine surgery	14.8	SA
Keita *et al.*[19]	42	Orthopedic, abdominal, urologic, hernia repair, anal, vascular, and thoracic surgery	17.3	SA
Lamonerie *et al.*[6]	19	Abdominal, thoracic, ENT, vascular, orthopedic surgery	57.9	SA
Li *et al.*[141]	31	Anorectal surgery	6	SA
Pavlin *et al.*[147]	68	Orthopedic, abdominal, ENT, plastic surgery	19	SA
Pawlowski *et al.*[62]	58	Orthopedic surgery	0	SA
Petersen *et al.*[54]	6	Orthopedic surgery	50	SA
Petros *et al.*[50]	111	Anorectal surgery	32	SA
Petros *et al.*[18]	145	Herniorraphy	8	SA
Ryan *et al.*[59]	105	Herniorraphy	17.9	SA
Salvati *et al.*[29]	176	Anorectal surgery	50.5	SA
Song *et al.*[143]	25	Herniorraphy	20	SA
Toyonaga *et al.*[31]	2,011	Anorectal surgery	16	SA
Valanne *et al.*[66]	99	Orthopedic surgery	1	SA
Young *et al.*[137]	93	Herniorraphy	18	SA
Zaheer *et al.*[28]	169	Hemorroidectomy	39.6	SA
Zaheer *et al.*[28]	194	Lateral internal sphincterotomy, fistulotomy, or incision/drainage	5.15	SA
Lingaraj *et al.*[26]	49	Orthopedic	12.2	EA, SA, CSE
Gedney *et al.*[108]	160	Orthopedic surgery	76	CSE
Iorio *et al.*[190]	393	Orthopedic surgery	62	SA, EA
Mulroy *et al.*[81]	32	Orthopedic surgery	0	SA. EA

CSE = combined spinal-epidural; EA = epidural anesthesia; ENT = eyes, nose, and throat; POUR = postoperative urinary retention; RA = regional anestesia; SA = spinal anesthesia.

sia, and its recovery depends on the duration of sensory block above the S2 and S3 sacral segments.

Time for sensory block to regress to S3 is 7–8 h after spinal injection of isobaric bupivacaine (20 mg), hyperbaric bupivacaine (21.5 mg), and hyperbaric tetracaine (7.5 mg) without significant difference between the three local anesthetics. Fifteen minutes after the level of analgesia regressed to L5 or lower (S2–S3), the strength of detrusor starts to return to normal values, allowing the patient to void.[58] Complete normalization of detrusor strength occurs 1–3.5 h after ambulation.[58]

The use of long-acting local anesthetics is related to a higher incidence of POUR.[52,53,59,60] In contrast, time to void after ambulatory surgery with short-acting and low-dose local anesthetics is shorter as a result of faster regression of sensory and motor block leading to a rapid recovery of bladder function.[61–64] Also, unilateral spinal anesthesia with hyperbaric bupivacaine for knee arthroscopy is associated with lower incidence of POUR and shorter time to void.[65,66] To our knowledge, no studies comparing the effect of the baricity of local anesthetics on bladder function have been conducted. According to the distribution of local anesthetics in the cerebrospinal fluid, the concentration of the hyperbaric local anesthetics in the sacral segments (S2–S3) is greater than that caused by an isobaric solution, suggesting that isobaric solutions a similar dose of a hyperbaric drug. In patients undergoing lumbar spine surgery, the incidence of POUR is lower when intrathecal local anesthetics are administered without opioids.[67,68]

Spinal opioids. Several studies on animals and on humans have consistently shown that spinal opioids influence bladder functions and cause urinary retention.[54,64,67–75] In rats, intrathecal and intracerebro ventricular morphine inhibits spontaneous bladder contractions and increases bladder capacity.[39,76] The block of micturition contraction occurs approximately 16 min after intrathecal morphine and lasts between 250 and 350 min. Re-

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Table 5. List of the Studies with the Incidence of POUR after Epidural Analgesia

Reference	Number of Patients	Type of Surgery	Incidence of POUR (%)	Conduction Blockade (Epidural Analgesia)
Basse *et al.*[166]	100	Abdominal surgery	9	Bupivacaine
Carli *et al.*[115]	32	Abdominal surgery	6.25	Bupivacaine + fentanyl
Paulsen *et al.*[112]	23	Abdominal surgery	13	Bupivacaine + fentanyl
Senagore *et al.*[116]	18	Abdominal surgery	5.5	Bupivacaine + fentanyl
Gurel *et al.*[107]	44	Anorectal surgery	79	Morphine
Evron *et al.*[111]	80	Cesarean section	26.2	Morphine, methadone
Husted *et al.*[90]	12	Gynecologic surgery	16.6	Morphine
Olofsson *et al.*[89]	1,000	Labor analgesia	2.7	Bupivacaine, sufentanil
Capdevila *et al.*[118]	17	Orthopedic surgery	53	Lidocaine + morphine
Gedney *et al.*[108]	160	Orthopedic surgery	71	Bupivacaine + diamorphine, or metadone, or morphine, or fentanyl, or pethidine
Gustafsson *et al.*[93]	10	Orthopedic surgery	20	Morphine
Lanz *et al.*[124]	57	Orthopedic surgery	71	Morphine
Lingaraj *et al.*[26]	29	Orthopedic surgery	24.1	NS
Reiz *et al.*[94]	15	Orthopedic surgery	20	Morphine
Singelyn *et al.*[117]	15	Orthopedic surgery	40	Bupivacaine + sufentanil
Toyonoga *et al.*[31]	1,442	Orthopedic surgery	19.3	Eptazocine
Walts *et al.*[183]	32	Orthopedic surgery	62	Morphine
Baron *et al.*[122]	34	Thoracic surgery	69.2	Fentanyl
Conacher *et al.*[86]	58	Thoracic surgery	31	Bupivacaine
Matthews *et al.*[133]	9	Thoracic surgery	66.6	Bupivacaine
Blanco *et al.*[113]	275	Neck and face, thoracic, abdominal, upper and lower limb, spine surgery	1.8	Bupivacaine + fentanyl
Niemi *et al.*[105]	12	Thoracic and upper abdominal surgery	0	Bupivacaine + fentanyl + epi
Barretto de Carvalho Fernandes *et al.*[114]	115	Orthopedic, thoracic, and neurosurgical surgery	24	NS
Ahuja *et al.*[110]	21	NS	0	Fentanyl
Evron *et al.*[41]	60	NS	28	Morphine
Reiz *et al.*[109]	1,200	NS	15	Morphine

Epi = epinephrine; NS = not specified; POUR = postoperative urinary retention.

appearance of the micturition reflex corresponds with the return of the nociceptive response.[39] In dogs, intrathecal fentanyl decreases bladder compliance and causes relaxation of internal urethral sphincter.[70] In humans, intrathecal opioids decrease the urge sensation and detrusor contraction, increasing the bladder capacity and the residual volume, altering sphincter function, and resulting in impaired coordination between the detrusor contraction and internal urethral sphincter relaxation.[71,72,76] The onset time and the duration of the these effects on bladder function depend on the type and the dose of opioid used, with a large variability in the recovery time.[71] In healthy volunteers, inhibition of the bladder occurred within 1 h after intrathecal morphine and sufentanil and lasted approximately 24 h. Morphine decreased the urge to void to a lesser degree than sufentanil. These effects were dose-dependent, and the recovery time of the functions of the bladder was shorter with sufentanil than with morphine. In a study conducted in subjects with spinal lesions up to the sacral region, intrathecal morphine reversed the urodynamic effects that the spinal lesion caused on bladder function.[72] These subjects had detrusor hyperreflexia (uninhibited detrusor contractions), vesicosphincter dysfunction, and vesicosomatic reflexes. Intrathecal morphine has been shown to enhance bladder capacity by increasing detrusor contractions and decrease vesicosomatic reactions.[72] The urodynamic effects of intrathecal opioids are mainly caused by the action on the opioid receptors in the spinal cord[71] and in the cerebral structures.[73] The rostral spread of opioids through the cerebrospinal fluid to the pontine micturition center has also been hypothesized as a possible mechanism of action of intrathecal opioids, but the rapid onset of the urodynamic effects with the concomitant onset of analgesia after intrathecal opioid injection and the reversal of the effects by intrathecal naloxone suggest a spinal site of action.[71] In support of this hypothesis, intrathecal naloxone in rats has been shown to reverse the urodynamic effects of systemic morphine at doses that were ineffective systemically.[76]

The opioids receptors involved in the urodynamic effects are μ and δ.[70,74–76] Buprenorphine, a partial agonist with poor affinity for μ and δ, has poor effect on the detrusor contraction and on the urethral sphincter.[70] Intrathecal opioids acting on opioid receptors in the spinal cord decrease the parasympathetic firing in the sacral region and decrease the afferent inputs from the bladder to the spinal cord.[39] De Groat *et al.* demonstrated that the axons of parasympathetic preganglionic neurons contain enkephalins that are transported in the parasympathetic ganglia.[77] These enkephalins seem to have an inhibitory modulating effect on the release of acetylcholine that causes detrusor contractions.[77] Intra-

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Table 6. List of the Studies with the Incidence of POUR after Systemic Analgesia

Reference	Number of Patients	Type of Surgery	Incidence of POUR (%)	Systemic Analgesia
Senagore *et al.*[116]	20	Abdominal surgery	0	PCA morphine
Carli *et al.*[115]	31	Abdominal surgery	0	PCA morphine
Paulsen *et al.*[112]	21	Abdominal surgery	4.8	PCA morphine
Imbelloni *et al.*[135]	50	Anorectal surgery	4	IV dipirone and ketoprofene
Petros *et al.*[21]	279	Appendicectomy	24.7	PCA morphine/meperidine or IM morphine or meperidine
Petros *et al.*[20]	360	Cholecystectomy	30	PCA morphine/meperidine or IM morphine or meperidine
Varrassi *et al.*[128]	95	Cholecystectomy	2.1	PCA morphine and IV NSAIDs
Petros *et al.*[18]	295	Herniorraphy	14	IM morphine/meperidine
Petros *et al.*[51]	366	Hysterectomy	16	PCA morphine/meperidine or IM morphine or meperidine
Capdevila *et al.*[118]	19	Orthopedic surgery	21	PCA morphine
Etches *et al.*[129]	174	Orthopedic surgery	21.8	PCA morphine and IV NSAIDs
Kumar *et al.*[184]	142	Orthopedic surgery	21.1	PCA morphine
Lanz *et al.*[124]	57	Orthopedic surgery	38	IM morphine
Lingaraj *et al.*[26]	96	Orthopedic surgery	3.1	PCA morphine, IM morphine
O'Riordan *et al.*[27]	116	Orthopedic surgery	21	PCA morphine, IM morphine
Peduto *et al.*[131]	97	Orthopedic surgery	1	PCA morphine and IV proparacetamol
Reiz *et al.*[94]	18	Orthopedic surgery	0	morphina IM
Singelyn *et al.*[117]	15	Orthopedic surgery	27	PCA morphine
Turner *et al.*[84]	20	Orthopedic surgery	0	PCA morphine
Walts *et al.*[183]	179	Orthopedic surgery	27	Morphine, meperidine IM
Fletcher *et al.*[127]	60	Spine surgery	20	PCA morphine, IV NSAIDs, and paracetamol
Hernandez *et al.*[130]	42	Spine surgery	17	PCA morphine and IV NSAIDs
Stallard *et al.*[6]	193	Abdominal surgery, mastectomy, thyroidectomy, varicose vein surgery	8	IV morphine
Barretto de Carvalho Fernandes *et al.*[114]	13	Orthopedic, thoracic, and neurosurgical surgery	12	PCA analgesia
Keita *et al.*[19]	123	Orthopedic, abdominal, urologic, hernia repair, anal, vascular, and thoracic surgery	20.3	IV morphine
Gonullu *et al.*[38]	577	Abdominal surgery and thyroidectomy	19.2	IV morphine and NSAIDs
Blanco *et al.*[113]	902	Neck and face, thoracic, abdominal, upper and lower limb, spine surgery	1.5	PCA morphine

IM = intramuscular; IV = intravenous; NSAIDs = nonsteroideal antiflammatory drugs; PCA = patient-controlled analgesia; POUR = postoperative urinary retention.

thecal fentanyl prolongs the duration of sensory block of spinal anesthesia with short-acting and long-acting local anesthetic without affecting the ability to void.[78,79] In outpatients, low-dose (20 mg) spinal lidocaine with small doses (25 μg) of fentanyl decreases the duration of sensory block and the time to void when compared with high-dose (50 mg) spinal lidocaine without fentanyl (130 *vs.* 162 min, respectively).[80] These results suggest that a low dose of local anesthetic alone[66,78,79] or in combination with a low dose of an opiate such as fentanyl[78–79]

Table 7. List of the Studies with the Incidence of POUR after Peripheral Nerve Blocks Used as Anesthesia or Analgesia Technique

Reference	Number of Patients	Type of Surgery	Incidence of POUR (%)	PNB
Imbelloni *et al.*[135]	50	Anorectal surgery	0	Bilateral pudendal nerve block
Bigler *et al.*[87]	10	Cholecystectomy	10	TPVB
Klein *et al.*[145]	20	Herniorraphy	0	TPVB
Song *et al.*[143]	28	Herniorraphy	0	IHNB
Brown *et al.*[132]	63	Orthopedic surgery	0	Interscalene block
Capdevila *et al.*[118]	20	Orthopedic surgery	0	CFB
Singelyn *et al.*[117]	15	Orthopedic surgery	13	CFB
Pavlin *et al.*[147]	76	Orthopedic, abdominal, ENT, plastic surgery, and others NS	6.6	IV regional block, axillary block, and other NS
Matthews *et al.*[133]	10	Thoracic surgery	10	TPVB

CFB = continuous femoral block; ENT = eyes, nose, and throat; INHB = ilioinguinal-hypogastric nerve block; IV = intravenous; NS = not specified; PNB = peripheral nerve block; POUR = postoperative urinary retention; TPVB = thoracic paravertebral block.

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Table 8. List of the Studies with the Incidence of POUR after Local Anesthesia or Local Infiltration

References	Number of Patients	Type of Surgery	Incidence of POUR (%)	LA
Bailey *et al.*[48]	17	Anorectal surgery	11.8	NS
Fleischer *et al.*[142]	52	Anorectal surgery	9.6	0.5% lidocaine + epi + local infiltration with 0.5% bupivacaine at the end of surgery
Li *et al.*[141]	31	Anorectal surgery	0	Sedation and after LI
Salvati *et al.*[29]	19	Hernioprraphy	31	NS
Sanjay *et al.*[136]	369	Herniorraphy	0.5	2% lignocaine + epi + 0.5% bupivacaine + sodium, bicarbonate
Pieper *et al.*[138]	381	Herniorraphy	0.9	NS
Finley *et al.*[144]	880	Herniorraphy	0.2	0.25% bupivacaine + epi
Young *et al.*[137]	101	Herniorraphy	7	1% lidocaine with or without epinephrine + 0.5% lidocaine to infiltrate around the ileoinguinal nerve and into the planes of dissection and repair
Zaheer *et al.*[28]	64	Herniorraphy	17	NS
Zaheer *et al.*[28]	74	Herniorraphy	0	NS
Pavlin *et al.*[147]	153	Orthopedic, abdominal, ENT, plastic surgery, and others NS	3.3	NS

ENT = eyes, nose, throat; epi = epinephrine; LA = local anesthesia; LI = local infiltration; NS = not specified; POUR = postoperative urinary retention.

may be a better way to minimize POUR and facilitate discharge of ambulatory patients without voiding.[80,82] Intrathecal morphine has a poor effect on the urethral sphincter,[71] whereas intrathecal fentanyl causes its relaxation.[70] This effect might be explained by the potent inhibitory property of fentanyl on the sympathetic fibers (T10-L2) that would otherwise increase the tone of the urethral sphincter.[70]

Epidural Local Anesthetics. Similar to intrathecal local anesthetic, epidural local anesthetics act on the sacral and lumbar nerve fibers, blocking the transmission of afferent and efferent nervous impulses from and to the bladder. The onset and the duration of the block would depend on the pharmacokinetic properties of the local anesthetic used. The incidence of POUR with epidural local anesthetics for inguinal herniorrhaphy has been shown to be lower than with spinal anesthesia.[83] Postoperative epidural ropivacaine 0.2% at different infusion rates was studied in a group of patients who underwent anterior cruciate ligament repair, and it was found that high infusion rate was associated with greater incidence of POUR and motor block.[84] Similarly, by using different concentrations (0.06% and 0.12%) of bupivacaine with sufentanil in patients receiving patient-controlled epidural analgesia after orthopedic surgery, there was a direct positive relationship between incidence of POUR and concentration of epidural bupivacaine.[85] POUR has also been reported after thoracic surgery patients receiving thoracic epidural analgesia with local anesthetic.[86]

Epidural Opioids. The urodynamic effects of epidural opioids have been studied extensively.[56,57,84–109] In a nationwide follow-up survey in Sweden, anesthesiologists reported a greater incidence of POUR with epidural morphine (38%) compared with intrathecal morphine (13%).[95] However, at close analysis, the patients that developed POUR had bladder catheterization as a result of the type and the duration of surgery, making assessment of POUR more difficult. The incidence of

Table 9. Overall Incidence of POUR after General Anesthesia, Conduction Blockade (Regional Anesthesia and Epidural Analgesia), Systemic Analgesia, Peripheral Nerve Blocks, and Local Anesthesia

	Number of Studies	Total Number of Patients	Mean (%)	SE	POUR 95% CI	POUR *P* Value	POUR OR
General anesthesia	26	5,268	17.2	0.1	16.9–17.5%	0.001*	0.68
Conduction blockade	34	5,105	23.3	0.3	22.7–23.8%		
Regional anesthesia (SA, EA, CSE)	26	4,013	19.9	0.3	19.4–20.4%		
SA	8	618	23.0	0.6	21.6–24.3%		
EA	26	4,870	17.6	0.2	17.2–18.9%		
Epidural analgesia (SI/II, CEI, PCEA)	27	4,360	14.7	0.2	14.0–15.0%		
Systemic Analgesia (PCA, IM, IV)	9	292	3.1	0.2	2.6–3.6%		
Peripheral nerve blocks	10	2,141	2	0.1	1.8–2.2%		
Local anesthesia							

* Overall incidence of postoperative urinary retention (POUR) after general anesthesia compared to the incidence of POUR after regional anesthesia.

CSE = combined spinal-epidural; CEI = continuous epidural infusion; EA = epidural anesthesia; IM = intramuscular; IV = intravenous; PCA = patient-controlled anesthesia; PCEA = patient-controlled epidural analgesia; SA = spinal anesthesia; SI/II = single injection/intermittent injection.

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Table 10. Incidence of POUR after General Anesthesia, Conduction Blockade (Regional Anesthesia and Epidural Analgesia), Systemic Analgesia, Peripheral Nerve Blocks, and Local Anesthesia, Sub-grouped by the Method Used to Define It

			POUR		
	Number of Studies	Total Number of Patients	Mean (%)	SE	95% CI
Clinical criteria					
General anesthesia*	9	2,913	18.8	0.2	18.5–19.2%
Conduction blockade					
Regional anesthesia (SA, EA, CSE)*	13	3,276	16.2	0.2	15.9–16.5%
Epidural analgesia (SI/II, CEI, PCEA)†	7	2,696	15.2	0.3	14.7–15.7%
Systemic analgesia (PCA, IM, IV)	9	2,208	19.8	0.2	19.5–20.1%
Peripheral nerve blocks	—	—	—	—	—
Local anesthesia	2	155	8.3	0.6	7.0–9.6%
Unspecified criteria or need of catheterization					
General anesthesia	15	1,926	14.9	0.3	14.3–15.4%
Conduction blockade					
Regional anesthesia (SA, EA, CSE)	18	1,728	36.6	0.6	35.4–37.8%
Epidural analgesia (SI/II, CEI, PCEA)	19	2,174	20.5	0.4	19.7–21.3%
Systemic analgesia (PCA, IM, IV)	17	2,029	6.9	0.2	6.5–7.4%
Peripheral nerve blocks	9	292	3.1	0.2	2.6–3.6%
Local anesthesia	8	1,986	1.5	0.1	1.4–1.7%
Ultrasound criteria					
General anesthesia	2	429	16.3	0.1	16.0–16.5%
Conduction blockade					
Regional anesthesia (SA, EA, CSE)	3	101	25.0	1.6	21.1–28.9%
Epidural analgesia (SI/II, CEI, PCEA)	—	—	—	—	—
Systemic analgesia (PCA, IM, IV)	1	123	20.3	—	—
Peripheral nerve blocks	—	—	—	—	—
Local anesthesia		—	—	—	—

Clinical criteria: * incidence of postoperative urinary retention (POUR) after general anesthesia compared to the incidence of POUR after regional anesthesia ($P < 0.001$, odds ratio (OR) = 1.20); † incidence of POUR after epidural analgesia compared to the incidence of POUR after systemic analgesia ($P < 0.001$; OR = 1.76).

CEI = continuous epidural infusion; EA = epidural anesthesia; IM = intramuscular; IV = intravenous; PCA = patient-controlled anesthesia; PCEA = patient-controlled epidural analgesia; SA = spinal anesthesia.

POUR after epidural opioids may also be related to the level at which opioids are injected. Administration of opioids in the lumbar epidural space is associated with higher rate of urinary retention compared to thoracic.[97]

Detrusor strength starts to decrease within 5–15 min after 4 mg of epidural morphine, its maximum effect reached between 30 and 120 min and lasting 10–15 h.[69,98] A supraspinal effect due to the rostral spread of opioids in the cerebrospinal fluid toward the pontine micturition center, where opioids receptors are placed, could poorly contribute to the development of POUR, as the onset of analgesia corresponds to the beginning of bladder relaxation and to the loss of detrusor strength.[69,71]

Naloxone *per se* has no effect on normal bladder function; however, it has been shown to reverse the urodynamic effects associated with epidural opioids.[69,90] By increasing the dose of IV naloxone, it is possible to prevent the decrease of detrusor contractions and the increase in bladder capacity.[69] Because of the short half-life of naloxone ($t_{1/2}$ = 1–1.5 h), the reversal effect on POUR could resolve before the effects of long-lasting opioids on the bladder. The urodynamic effects are not dose-dependent as shown for intrathecal opioids.[69,71,99,100] The reason for this difference could be explained by the different route of administration, as spinal opioids suppress polysynaptic reflexes in a dose-dependent manner.[71]

Different epidural opioids have different urodynamic effects depending on their pharmacokinetic properties and receptor selectivity.[97] In a study by Kim *et al.*, patients undergoing gastric bypass surgery receiving postoperative thoracic epidural with either ropivacaine and sufentanil or ropivacaine and morphine in equipotent doses, the incidence of POUR was greater with the latter mixture.[101] In another study on postpartum urinary retention, the incidence of POUR after epidural bupivacaine and epinephrine was less than epidural bupivacaine and sufentanil.[89] Sufentanil and fentanyl are more lipophilic than morphine and undergo greater systemic uptake; as a result, there is less rostral spread in the central nervous system and less influence on the urodynamics.[110] In contract, the hydrophilic nature of morphine delays its systemic uptake; more morphine is therefore available at the lumbar region, directly inhibiting the neurons controlling the bladder. For similar reasons, the incidence of POUR was also found to be less with epidural buprenorphine as compared with epidural morphine.[102] In addition, buprenorphine, a partial agonist with poor affinity for μ and δ receptors, has minimal effect on the detrusor contraction and on the urethral

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sphincter.[70] Also epidural methadone and meperidine were shown to be associated with less incidence of POUR.[108,111]

Although it has been suggested that the dose of epidural opioid may influence the incidence of POUR, this has yet been not confirmed or corroborated in the literature. Rucci *et al.* studied the side effects of epidural bupivacaine alone and with varying doses of fentanyl (50 to 200 μg) to bupivacaine in the lumbar epidural space in patients undergoing lower abdominal surgery. Micturition abnormalities were observed in all the groups, without significant differences, but the patients that received fentanyl needed catheterization.[103]

Opioids and Epinephrine as Adjuvants. The addition of opioids to epidural local anesthetics increases the risk of POUR and urinary tract complications, such as renal failure and cystitis by 8%.[96] The incidence of POUR is 5 to 20% higher in patients with continuous epidural infusion or patient-controlled epidural analgesia compared with PCA,[112–118] 13.1% with continuous epidural infusion and 5.2% with patient-controlled epidural analgesia.[119] Ephinephrine is used as adjuvant to prolong the effect of neuraxial anesthesia,[88,104,105] resulting in longer recovery of sensory and motor block with possible consequences on bladder function.[120–122]

Postpartum Urinary Retention and Epidural Anesthesia-Analgesia. Postpartum urinary retention is a frequent complication and this appears to be the result of the pressure from the uterus on the body of the bladder.[89] Urodynamic studies have shown that 85% of parturients investigated had bladder hypotonia after delivery with a consequent increase in bladder volume.[89] Epidural anesthesia-analgesia, which is often used during labor and delivery, has been shown to cause postpartum urinary retention.[123] Olofsson *et al.* observed a significantly higher incidence of postpartum urinary retention in parturients that received epidural with two different epidural mixtures (bupivacaine 0.25% with adrenaline 1:200,000 or bupivacaine 0.125% with 10 μg of sufentanil) than women who did not receive epidural. At a close analysis, those women receiving epidural anesthesia had higher incidence of instrumental deliveries and difficult labor. Therefore, it is not clear whether the effect on postpartum urinary retention was a direct effect of epidural blockade or resulted from the instrumentation and difficult labor. No difference in urinary retention was found when either epinephrine or sufentanil was added to bupivacaine.[89] In contrast, Evron *et al.* observed less incidence of urinary retention when epidural methadone was used after Cesarean section.[111]

Systemic Analgesia. Systemic opioids both by the IV and intramuscular routes have a direct effect on bladder function[40,57,69,92–94,111,124,125] *via* their action on spinal cord receptors. This effect is reversed by intrathecal naloxone.[76,77] Systemic opioids cause POUR by inhibiting the release of acetylcholine from the parasympathetic sacral neurons that control detrusor contractility.[20,21] In patients undergoing cholecystectomy and appendectomy the incidence of POUR has been shown to be directly related to the amount of systemic opioids used in the postoperative period. Furthermore, the incidence of POUR was greater if patients received intravenous PCA technique instead of intramuscular morphine or meperidine, suggesting that the steadier/steady plasma opioid concentration obtained with PCA was indirectly responsible for prolonging the effect on bladder function. Ketamine, nonsteroidal antiinflammatory drugs, and proparacetamol used together with morphine (delivered by PCA) have a morphine-sparing effect and have shown to decrease the incidence of POUR by 20%.[52,126–131]

Peripheral Nerve Block. POUR has not been reported with interscalene block.[132] Paravertebral block and intercostal block in patients undergoing thoracotomy and cholecystectomy, respectively, were associated with less incidence of POUR compared to epidural or PCA.[106,133,134] Capdevilla *et al.* and Singelyn *et al.*, comparing the efficacy and the side effects of three analgesic techniques for major knee surgery, found the incidence of POUR significantly lower in those patients receiving peripheral nerve block compared with epidural and PCA.[117,118] In patients undergoing anorectal surgery, bilateral pudendal block decreases also the incidence of POUR.[135]

Infiltration of Local Anesthetics. Field block or infiltration technique is commonly used for herniorraphy and anorectal surgery. Pain is an important factor found in the development of POUR after herniorrhaphy, and local anesthetic infiltration has been shown to decrease analgesic requirements and the risk of POUR.[136–139] Similarly, perineal pain and tension in the anal canal after anorectal surgery cause sphincter spasm and detrusor relaxation.[140] In a randomized study of patients undergoing anorectal surgery, Li *et al.* found no difference in the incidence of POUR among the patients who received either general anesthesia or regional anesthesia or local infiltration. However, at a close analysis, the two former groups had the anorectal area infiltrated with local anesthetic, making it difficult to identify whether general and regional anesthesia influenced POUR.[141] In contrast with these findings, a prospective study by Fleischer *et al.* showed that patients undergoing anorectal surgical procedures under local anesthesia had less urinary retention then patients who received spinal anesthesia.[142] Cataldo *et al.* and Ryan *et al.* reported a higher incidence of POUR after local infiltration in patients undergoing anorectal surgery (49%) and herniorraphy (17.9%).[32,59] However, all patients received spinal or epidural anesthesia for surgery, rendering it difficult to assess the potential benefits of local anesthetic infiltration on POUR. Long-acting local anesthetics are advocated for herniorraphy. The reduction in acute postoperative pain

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afforded by the long-acting local anesthetics may potentially attenuate the inhibition of bladder reflexes that increase the risk of POUR.[59,60,143,144] Furthermore, long-acting local anesthetics could facilitate, in the absence of motor block, early postoperative mobilization; allowing the patient to contract the abdominal muscles and to stand up to facilitate the emptying of the bladder.[143] Paravertebral nerve block for herniorrhaphy has also been found to be associated with lower incidence of POUR.[145]

Complications/Adverse Effects Associated With POUR

Autonomic Response

Painful stimulation resulting from an overdistended bladder can cause vomiting, bradycardia, hypotension, hypertension, cardiac dysrhythmias, or even asystole.[52] POUR has been shown to prolong hospital stay in patients undergoing elective cholecystectomy[20] and increase the discharge time in 19% of outpatients.[146,147]

Infection

Urinary infection can be a direct complication of persistent POUR (consequence of bladder hypotonia and the inability to completely empty the bladder) or an indirect complication of bladder catheterization.[148] Higher mortality rate has been reported in hospitalized patients who developed nosocomial urinary tract infection after indwelling bladder catheterization.[149] The incidence of bactremia after single catheterization has been reported to be as high as 8%.[150] Akthar *et al.* found that 21% of women undergoing laparoscopic surgery that had been catheterized before the procedure had bacteriuria 6 days later.[151] The use of an indwelling catheter after total joint replacement surgery for 24 h or less decreased the incidence of POUR without increasing the incidence of urinary tract infections.[152] Complications have also been reported with in-out and intermittent catheterization techniques.[153]

Bladder Overdistension and Adverse Effects on Urodynamics

Bladder overdistension is a potentially serious adverse effect associated with POUR, and it has a reported incidence of 44%.[7] In a study by Pavlin *et al.*, 20.5% of outpatients had a bladder volume greater than 500 ml.[4] Mulroy *et al.* set up a target volume of 400 ml in a study of outpatients undergoing ambulatory surgery under spinal and epidural anesthesia. Eighteen percent of the patients assessed with ultrasound had a bladder volume greater than 400 ml, and only 13% of these patients required catheterization due to inability to void.[53] On the basis of animal studies, bladder ischemia may be responsible for the persistent dysfunction after bladder over distension.[154] Furthermore, Katida *et al.* observed that, if the rabbit bladder was overdistended for a period of time between 4 and 24 h, the concentration of muscarinic receptors decreased, resulting in reduced detrusor contractility.[154] Transient filling volume between 500 and 1,000 ml is not harmful if it is diagnosed and treated early within 1 to 2 h.[4] Tammela showed in patients undergoing inpatient surgery that an initial volume over 500 ml detected by in-out bladder catheterization, increased the incidence of persistent POUR when compared with an initial volume below 500 ml. However 51% of these patient were catheterized after 12 h, and 38% had a bladder volume greater than 1,000 ml, suggesting that an early catheterization could have decreased the incidence of prolonged micturition difficulties.[23] It is thus logical to investigate further and establish safe bladder volume ranges to avoid bladder overdistention and persistent bladder dysfunction.

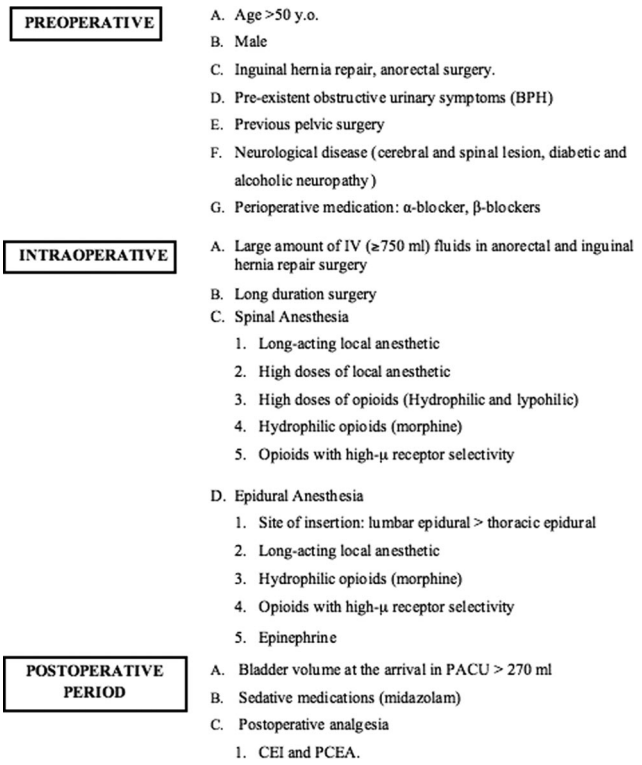

Fig. 3. Risk factors for POUR. BPH = benign prostatic hypertrophy; CEI = continuous epidural infusion; IV = intravenous; PACU = postanesthesia care unit; PCEA = patient-controlled epidural analgesia; POUR = postoperative urinary retention.

Clinical Management of POUR

Prevention of POUR requires the identification of patients with perioperative risk factors (fig. 3). Pharmacological strategies have been used as an attempt to prevent or to treat persistent POUR (fig. 4). Systemic phentolamine has been shown to decrease the resistance of IUS in rats,[155] whereas phenoxybenzamine reduces

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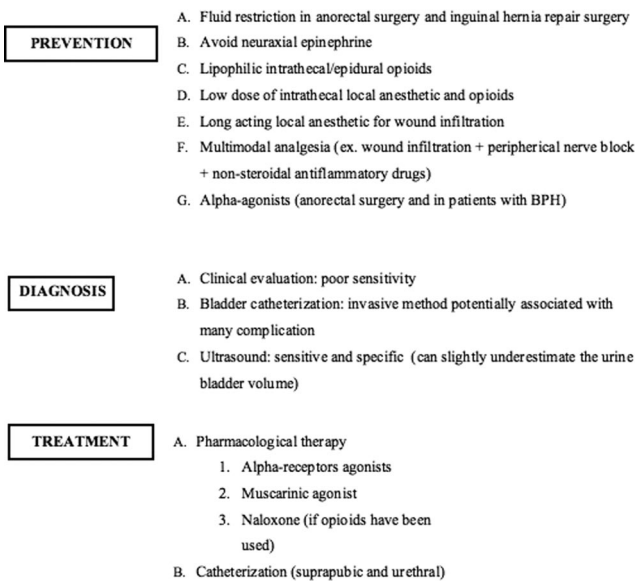

Fig. 4. POUR: prevention, diagnosis and treatment. BPH = benign prostatic hypertrophy; POUR = post operative urinary retention.

the time to first void and the incidence of bladder catheterization.[41,43] In a prospective randomized study Goldman *et al.* showed that phenoxybenzamine was effective in preventing and treating POUR in patients undergoing inguinal hernioplasty.[156] Similar effect was shown in different types of surgery[157] and in patients with prostate enlargement undergoing anorectal surgery.[158] In contrast, phenoxybenzamine failed to prevent POUR after anorectal surgery.[32] In conclusion, the use of phenoxybenzamine remains controversial.

Postoperative pain, rectal distension, and anal dilatation increase sympathetic tone. The resultant stimulation of the α-receptors in the IUS leads to increased pressure on the bladder neck and potentially to POUR. It has been hypothesized that this physiologic mechanism could explain urinary retention after anorectal surgery. Therefore, the use of α-antagonists in patients with postoperative pain after anorectal surgery could decrease the incidence of POUR.[32] Further studies are needed to establish the role of these agents in the prevention of POUR among patients undergoing anorectal surgery.

In the following section, practical guidelines addressing clinical questions are proposed on the basis of a literature review and documented findings.

Role of Bladder Catheterization

Bladder catheterization is the standard treatment of POUR. Although in-out and indwelling urinary catheterization remain the standard therapy to treat POUR, it is not known which patients require catheterization, and the duration of catheterization and bladder volume thresholds are also unknown. Some of these issues are addressed on the basis of currently available evidence.

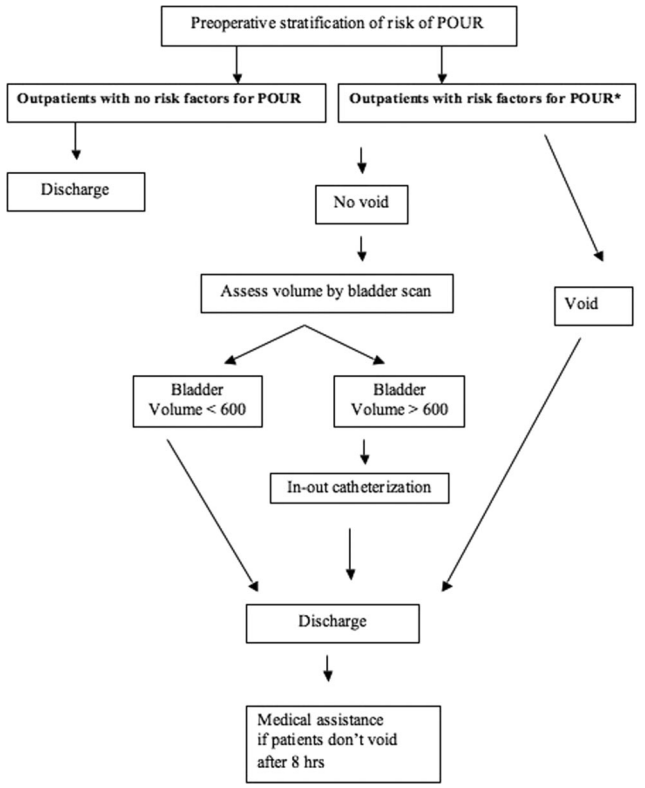

Fig. 5. Postoperative urinary retention (POUR): Management for outpatient surgery. * If high-risk patients void spontaneously, they can be discharged after the residual volume is checked.

When and in Whom Should the Bladder Be Catheterized?

By selecting patients who need a bladder catheter, the likelihood of urinary complications may be potentially minimized. Bladder catheterization, while preventing persistent voiding dysfunction secondary to bladder overdistension, may be associated with urinary tract infections, urethral trauma, and patient discomfort.[8] Ultrasound assessment of bladder volume remains an accurate method.[9–15] The bladder volume at which one may decide to catheterize depends on the preoperative bladder functional capacity and the ability to void. Normal bladder capacity ranges between 400 to 600 ml.[7,52] To easily measure functional bladder capacity to avoid invasive methods, Brouwer *et al.* suggest holding the urine until the desire to void is uncomfortable and then measuring the urinary volume that the patient voids.[9] If POUR is diagnosed early (within 1–2 h), transient bladder distention with 500 to 1,000 ml volume may not have adverse effects on voiding function. At a volume 600 ml, catheterization is recommended.[4] This volume is slightly higher than the maximum bladder volume of 400–500 ml recommended in the adult population.[15]

In summary, low-risk outpatients may be discharged without void, and bladder catheterization is advised in high-risk subjects when the bladder volume is greater than 600 ml over a minimum period of 2 h (fig. 5).

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How Long Must Surgical Patients Need Keep the Bladder Catheter?

Catheterization of the bladder is required for monitoring urinary output after major surgery, guiding volume resuscitation and preventing POUR. However, both intermittent and indwelling bladder catheterization have been associated with urinary tract infections.[148,149,159,160] Aseptic techniques during the placement of bladder catheter and antibiotic prophylaxis have been reported to reduce the incidence of urinary tract infections.[161,162] POUR in ambulatory surgery is commonly treated with in-out catheterization. For in-hospital patients, the optimal duration of bladder catheterization remains controversial. In a heterogenous surgical population, in-out catheterization was compared to indwelling catheterization for 24 h. No differences in terms of recatheterization and urinary tract infections were found between the two strategies, but indwelling catheterization increased hospital stay by 1 day.[22] For anorectal surgery, most authors suggest 5 days with a range between 3 and 10 days.[35,163–165] The incidence of urinary tract infections after anorectal surgery and 5 days of catheterization ranges between 42% and 60%.[33,36,165] The incidence of POUR after anorectal surgery was similar whether patients had an indwelling catheter for either 1 day or 5 days, but a lower incidence of urinary tract infections was reported in the 1-day group. Preoperative dysuria and metastatic lymph node disease in patients with rectal cancer were identified as risk factors of POUR. The recommendations are that patients undergoing anorectal surgery with no other risk factors for POUR should keep the catheter for 1 day to reduce the risk of urinary tract infections, whereas patients at high risk (rectal cancer, preoperative dysuria, and metastatic lymph nodes) should keep the catheter for 5 days.[36] Basse *et al.* studied the incidence of POUR, urinary tract infections, and permanent voiding dysfunction after colonic resection in 102 patients, catheterized for only 24 h, and continuous epidural bupivacaine-morphine infusion. These authors reported a low incidence of POUR (9%) and urinary tract infections (4%). None of the patients had long-term voiding dysfunction.[166] However, because of the absence of a control group and the absence in literature of large prospective randomized studies, further investigations are needed to establish the optimal duration and the necessity of bladder catheterization during continuous epidural analgesia. Removal of the bladder catheter after abdominal or vaginal hysterectomy and vaginal prolapse surgery either immediately[167,168] or within the first 24 h has been shown to decrease the incidence of postoperative urinary infections and duration of hospitalization without increasing the risk of bladder dysfunction.[167,169–171]

In summary, the results of a few randomized studies suggest that intermittent catheterization is adequate for outpatient surgery. For major uncomplicated surgery with or without epidural anesthesia/analgesia, bladder catheterization may be limited to a period of 24 h. Ultrasound may be used to guide catheterization if urine volume exceeds 600 ml and in-out catheterization technique may be preferable. For major complicated surgery and with extensive perineal and rectal dissection, bladder catheterization is required for a longer period of time according to clinical indications.

Is Bladder Catheterization Necessary for Surgical Patients Undergoing Lower Limb Joint Surgery?

Urinary tract infection related to bladder catheterization is a well known postoperative complication in patients undergoing orthopedic surgery.[150,172–175] Hematogenous spread from the urinary tract could potentially infect the prosthetic joint or disseminate systemically, causing severe complications, including sepsis.[173,175–179] Postoperative bacteriuria has been shown to increase 3 to 6 times the risk of prosthetic infection,[178,180,181] with male patients at higher risk of developing POUR.[174,175,182,183] Epidural morphine is associated with an incidence of 62% of POUR compared with 24% when systemic opioids are used.[183] Some data seem to indicate that indwelling bladder catheter in patients at risk of POUR might be advantageous over intermittent catheterization with less POUR and no change in incidence of urinary tract infection.[25,152,184–186] No difference in urinary tract infections has been found when either an indwelling bladder catheterization for 24 h or intermittent catheterization techniques were used.[187] With regard to the latter, an increased risk of undiagnosed bladder overdistension resulting in risk of permanent bladder dysfunction and secondary urinary tract infections has to be considered. Short-term antibiotic prophylaxis, limited to one dose of cefazolin before the surgery, is associated with less bacteriuria with intermittent bladder catheterization than with indwelling catheterization.[188] Currently, bacterial resistance and increased costs are the main reasons for the choice of short-term antibiotic prophylaxis in patients undergoing total joint replacement.[181,189] This approach does not cover the period of indwelling bladder catheterization; therefore, it may increase the risk of urinary tract infections.[188] Although POUR after total joint arthroplasty has been shown to occur frequently (67%) in patients who receive intermittent catheterization as necessary, routine preoperative catheterization may not be warranted, except when high risk factors for POUR are present.[187,190] If POUR occurs and catheterization is required, intermittent catheterization is the preferable choice, and it has been shown to be more cost-effective than indwelling catheterization.[187,190]

In summary, bladder catheterization is not required in low-risk patients receiving neuraxial lipohilic opioids, whereas bladder catheterization is recommended in high-risk patients for 24 h under adequate anthibiotic

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prophylaxis. Subsequent in-out catheterization should be guided by ultrasound.

Must Outpatients Void before Being Discharged?

Ability to void has always been considered as one of the criteria to discharge outpatients. By stratifying preoperative risk for POUR, selected patients could be discharged without voiding.[4,5,53] In two prospective studies by Pavlin *et al.*, outpatients were classified as low-risk for POUR if they had general anesthesia or nonpelvic surgery and high-risk if they had hernia/anal surgery or spinal/epidural anesthesia.[4,5] In low-risk outpatients, the incidence of POUR (defined as the inability to void with a bladder volume greater than 600 ml detected by ultrasound) was less than 1% compared to 15% in the high-risk group. Of 227 low-risk patients, 1 patient had POUR. The others voided approximately 75 min after surgery and were discharged without voiding. In the high-risk patients, the incidence of POUR was 5%; when they were catheterized (in-out catheterization at a bladder volume greater than 600 ml), the incidence of urinary retention was high (25%). According to these published findings, low-risk patients undergoing ambulatory surgery could be discharged without voiding, whereas high-risk patients who have been catheterized before discharge may require medical assistance if not able to void spontaneously within 8 h from surgery. If ultrasound equipment is not available and high-risk patients do not void before discharge, then they should be catheterized.[5] Ultrasound remains a useful instrument in high-risk patients not only because it measures bladder volume; it also guides timing of the catheterization and thus avoids unnecessary bladder and catheter-related complications and delayed disharges (fig. 5).

In summary, outpatients in the low-risk category group can be sent home without voiding, but those in the high-risk group can be catheterized under ultrasound guidance and then sent home with medical assistance.

In conclusion, several anesthetic and nonanesthetic factors contribute to the development of POUR in the surgical patient. The diagnosis of POUR is often arbitrary, and its true incidence is unknown due to lack of defining criteria. By carefully identifying patients at risk, adopting appropriate anesthetic techniques and perioperative care principles and accurately monitoring bladder volume by ultrasound, POUR may be prevented and the associated morbidity minimized. Hence it becomes imperative to evaluate the true incidence and consequences of POUR in large prospective clinical trials.

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