



Beyond Analgesia: Neuraxial Adjuvants, Sacral Bladder Recovery, and Urinary Retention After Orthopedic Surgery

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Received: 28 October 2024, **Accepted:** 17 November 2024, **Published:** 20 November 2024

Abstract

Background: Postoperative urinary retention (POUR) is an important but incompletely characterized complication of spinal anesthesia for lower limb orthopedic surgery. Although intrathecal adjuvants enhance the quality and duration of bupivacaine anesthesia, improved analgesia does not necessarily translate into earlier recovery of micturition. This narrative review integrates lower urinary tract neurophysiology, the pharmacology of bupivacaine and its two commonly investigated adjuvants—fentanyl and dexmedetomidine—and clinical evidence on postoperative voiding. The sensory pathways required for awareness of bladder filling and the sacral parasympathetic pathways coordinating detrusor contraction are susceptible to neuraxial blockade. Fentanyl acts predominantly through spinal opioid receptors, whereas dexmedetomidine facilitates regional analgesia through alpha-2 adrenergic mechanisms. Comparative trials and meta-analyses generally show more sustained sensory and motor blockade with intrathecal dexmedetomidine, but most were not powered to assess urinary outcomes. The directly relevant knee-arthroscopy trial did not demonstrate a statistically significant difference in POUR between the two adjuvants. Other investigations show that dexmedetomidine may postpone first voiding when it extends the duration of a short-acting spinal anesthetic. Variability in bladder-volume thresholds, patient selection, fluid management, timing of assessment, and definitions of retention complicates between-study comparisons. A practical approach combines risk identification, individualized spinal anesthetic selection, serial ultrasonographic surveillance, symptom assessment, and clearly specified catheterization criteria. Future adequately powered trials should measure sacral sensory recovery, spontaneous voiding, residual bladder volume, and catheterization separately. Selecting an intrathecal adjuvant should balance postoperative analgesia against motor recovery, bladder function, cardiovascular effects, and readiness for discharge.

Keywords: Spinal anesthesia, Dexmedetomidine, Fentanyl, Postoperative urinary retention

Introduction

Spinal anesthesia has a central role in modern lower limb orthopedic practice because it provides reliable intraoperative anesthesia while limiting airway instrumentation and facilitating multimodal recovery pathways. Yet the duration of a subarachnoid block is not synonymous with its clinical usefulness. Patients must regain adequate movement, autonomic function, and urinary control before safe discharge. Intrathecal bupivacaine remains a familiar reference local anesthetic, and anesthesiologists increasingly modify its effects by adding small doses of drugs acting at spinal receptor systems. Fentanyl and dexmedetomidine are important examples, with distinct receptor targets and different time courses of sensory, motor, and autonomic effects. The resulting choice concerns far more than postoperative pain scores. It also concerns whether stronger or longer blockade compromises a patient's ability to mobilize, recognize a full bladder, and void after surgery. [1,2]

Postoperative urinary retention is commonly defined as failure to empty a distended bladder after an operation. Its observed frequency ranges widely because investigators use different definitions, populations, and thresholds for intervention. A patient unable to void with a bladder volume greater than 600 mL is not necessarily classified identically to a patient catheterized at 400 mL or monitored conservatively until 800 mL. These differences can transform the recorded incidence without changing the underlying biology. Retention is clinically consequential: untreated overdistension may injure detrusor function, and catheterization causes discomfort, introduces infection risk, and can obstruct timely discharge. In ambulatory orthopedics, detecting an asymptomatic distended bladder is especially important because an absent urge is a predictable manifestation of sacral neural blockade rather than proof that the bladder is empty. [3,4]

The principal research gap is the mismatch between the outcomes usually assessed in comparative neuraxial-adjuvant studies and the outcomes needed to judge recovery of micturition. Most trials report onset, dermatomal regression, Bromage recovery, analgesic consumption, and cardiovascular adverse events; relatively few systematically measure bladder volume or independently adjudicate postoperative urinary retention. A longer



sensory block may provide analgesic benefit while extending the interval during which bladder sensation is absent. Conversely, a drug with an opioid-sparing profile cannot automatically be assumed to preserve sacral parasympathetic function. The clinically important question is therefore not which drug produces the longest blockade, but whether its analgesic advantage remains favorable when bladder recovery, catheterization, mobility, and discharge are evaluated together. [5,6]

Aim

This review examines the physiological basis and clinical relevance of postoperative bladder dysfunction after spinal anesthesia and critically compares the effects of intrathecal fentanyl and dexmedetomidine, particularly when combined with bupivacaine for lower limb orthopedic procedures.

The burden of urinary retention in orthopedic recovery

Orthopedic patients encounter an unusually broad mixture of urinary risk factors. Those undergoing knee arthroscopy may be relatively young and suitable for same-day discharge, whereas hip-fracture and arthroplasty populations frequently have advanced age, restricted mobility, chronic urinary symptoms, and substantial exposure to postoperative opioids. Fluid administration, long procedures, pain, and delayed access to a toilet can interact with the anesthetic technique. In a multicenter prospective fast-track hip and knee arthroplasty cohort, Bjerregaard and colleagues found catheterization-defined POUR in 40% of patients, with considerable variation between departments and a modest association with spinal anesthesia. The result cannot be transported directly to arthroscopy populations because the operations, baseline risk, and urinary surveillance protocols differ. [7,8]

Preoperative urinary complaints need more careful attention than a simple history of previous retention. Increased International Prostate Symptom Scores among men who required catheterization in arthroplasty suggest that lower urinary tract symptom burden can signal vulnerability even when patients ordinarily void without assistance. Age, benign prostatic obstruction, diabetes, neurologic disease, chronic medication exposure, and prior pelvic surgery may modify the response to postoperative anesthetic blockade. Associations differ by procedure and analytical model: spine-surgery meta-analyses, for example, consistently identify age and selected comorbidities as risk factors but represent populations in which direct neural manipulation can itself impair voiding. Clinicians should avoid treating findings from spinal surgery as equivalent to those from an isolated knee operation under spinal anesthesia. [7,9,10]

The burden of retention is not limited to the proportion receiving a catheter. Postponed mobilization can interrupt physiotherapy, and an uncomfortable distended bladder can aggravate postoperative agitation, hypertension, or pain. In older adults, unfamiliar surroundings, restricted mobility, and inability to communicate urinary urgency may make symptoms difficult to interpret. Catheterization may be necessary to protect detrusor function, yet repeated insertion adds urethral trauma and infectious exposure. A useful evaluation must therefore record both under-treatment and over-treatment: a protocol that avoids catheters at the cost of prolonged extreme overdistension is undesirable, just as a protocol that catheterizes every moderately full asymptomatic bladder may generate unnecessary procedures. [3,11]

Neural architecture of normal micturition

Storage and voiding require coordinated regulation of the detrusor, bladder outlet, and pelvic floor. During the filling phase, sympathetic activity from thoracolumbar pathways favors detrusor relaxation and outlet resistance, while pudendal somatic motor activity supports voluntary external sphincter closure. In contrast, voiding requires coordinated activation of parasympathetic pathways originating in S2–S4, suppression of outlet guarding, and relaxation of the external sphincter. Stretch-sensitive afferents signal progressive filling through pelvic nerves toward spinal and supraspinal networks. These pathways explain why bladder sensation, detrusor pressure generation, outlet relaxation, and actual urine flow are related but not interchangeable physiological variables. [12,13]

The pontine micturition center coordinates a complex switch between storage and emptying under voluntary control from cortical and subcortical networks. Successful voiding is not simply a forceful detrusor contraction; outlet resistance must decrease at the correct moment, and the individual must be able to recognize bladder filling and initiate the behavioral sequence. Pathological states can uncouple these components. Reduced afferent signaling can suppress urgency despite rising volume, weakened efferent activation can produce ineffective detrusor contraction, and pain-related sympathetic activity can oppose emptying even after sensory recovery. This integrated framework helps explain why a bedside report of “no desire to urinate” is an unreliable exclusion test for clinically important postoperative bladder filling. [12,13]

Sacral neural blockade and timing of recovery

Spinal local anesthetics interrupt impulse conduction within neural roots exposed to subarachnoid drug. Somatic sensory and motor responses, sympathetic tone, and pelvic autonomic function may recover at different rates.



Urodynamic investigations show that perception of bladder filling is lost rapidly after spinal injection, and normal detrusor behavior may take considerably longer to return than movement in the lower limbs. Classic physiological measurements documented that detrusor activity could remain impaired for seven to eight hours under some local anesthetic regimens, while restoration of lower limb strength occurred substantially earlier. Thus the ability to move the ankles or transfer from bed cannot be used as a dependable surrogate for safe spontaneous voiding. [14,15]

The relationship between sacral sensory regression and urinary recovery is particularly informative. In men receiving spinal lidocaine or bupivacaine for minor orthopedic procedures, the urge to void disappeared promptly after injection and spontaneous micturition did not return until sensory analgesia had regressed to the S3 segment. Detrusor blockade lasted substantially longer with bupivacaine than with lidocaine, with greater accumulation of urine during the anesthetic period. This observation connects anesthetic duration to overdistension risk through a plausible physiological chain, although small mechanistic studies cannot provide a precise bedside prediction for each patient. Surgical factors, baseline urinary performance, and perioperative filling rates still contribute importantly to individual variation. [15,16]

Bupivacaine as the pharmacological platform

Bupivacaine is an amino-amide local anesthetic that inhibits voltage-gated sodium channels and therefore blocks the propagation of impulses along exposed nerve fibers. Hyperbaric solutions are frequently used to achieve a predictable distribution of subarachnoid anesthesia for lower limb procedures, although block height depends on posture, injected dose, spinal anatomy, and patient characteristics. Its relatively long duration gives dependable conditions for orthopedic operations of moderate length. The same persistence becomes less welcome during short ambulatory procedures because autonomic and motor recovery can outlast the surgery by several hours. The clinical aim is therefore to match the minimum effective local anesthetic dose and its adjunctive effects to the likely procedural duration rather than maximize block persistence. [1,16]

Dosage strategies illustrate a recurring tension in ambulatory spinal anesthesia. Small quantities of bupivacaine combined with opioid supplementation may produce adequate surgical anesthesia without the recovery profile of larger local anesthetic doses. In an arthroscopy trial, low-dose dilute bupivacaine plus 10 micrograms of intrathecal fentanyl improved characteristics of the block without significantly prolonging time to urination or discharge relative to the same dilute bupivacaine alone. Such observations should not be extrapolated automatically to 12.5–15 mg bupivacaine schedules, in which baseline sacral blockade is more substantial. The effect of an adjuvant depends on the pharmacological context, and the absolute dose of local anesthetic is a crucial co-determinant of early recovery. [17,18]

Fentanyl: spinal analgesia and bladder effects

Fentanyl is a lipophilic opioid receptor agonist whose intrathecal effect is predominantly mediated through opioid receptors in the spinal cord. Its addition to bupivacaine can enhance analgesia while limiting the need to increase local anesthetic dose. Compared with hydrophilic morphine, fentanyl has different cerebrospinal-fluid kinetics and generally produces a shorter neuraxial opioid effect. This distinction matters for pruritus, delayed respiratory depression, and urinary function, but it does not render fentanyl physiologically neutral toward micturition. Opioid signaling can reduce the perception of filling and suppress detrusor contractile activity, and the resulting urinary effects vary with dose and the accompanying local anesthetic. [19,20]

Direct studies with intrathecal opioids clarify why observations made with morphine or sufentanil should not be quoted as measured fentanyl effects without qualification. In a small urodynamic investigation, addition of intrathecal sufentanil to lidocaine affected lower urinary tract function despite an anesthetic strategy intended to allow relatively rapid somatic recovery. A separate trial of small-dose bupivacaine with graded fentanyl supplementation found later mobilization, micturition, and discharge at higher fentanyl doses, supporting dose dependence within that particular setting. These studies indicate biological plausibility rather than a universal magnitude of fentanyl-associated retention, and they should be interpreted alongside the dominant influence of local anesthetic dose. [20,21]

The practical attraction of fentanyl is that a modest intrathecal dose can improve the adequacy of shorter spinal blocks without generating the marked alpha-2-mediated prolongation of motor block seen with dexmedetomidine in many trials. It may be useful where early mobility is a high priority or the procedure is too brief to justify a prolonged sensory and motor block. Its limitations include pruritus, nausea, and opioid-related effects on urinary function. Moreover, the association between intrathecal opioids and retention is strongest for morphine in prevention reviews; conclusions derived from replacing morphine in regional regimens should not be presented as proof that fentanyl and dexmedetomidine have a specific relative effect on POUR. [5,22]

Dexmedetomidine: spinal alpha-2 receptor pharmacology

Dexmedetomidine is a highly selective alpha-2 adrenergic agonist with sedative, sympatholytic, and analgesic-sparing properties. Its established systemic pharmacology includes actions within the locus coeruleus and other



central autonomic pathways, while spinal administration is thought to inhibit nociceptive neurotransmission and facilitate the action of local anesthetics at spinal neuronal circuits. These mechanisms differ fundamentally from fentanyl's mu-opioid receptor agonism. The distinction offers a rationale for reduced opioid-related adverse effects, particularly pruritus, but it must not be confused with direct evidence that the drug preserves detrusor contraction. The autonomic control of micturition also contains adrenergic pathways, and the net clinical response cannot be predicted from receptor selectivity alone. [23,24]

Randomized trials commonly use intrathecal dexmedetomidine in microgram doses, often 3–10 micrograms, as an adjunct rather than as a sole spinal anesthetic. At 5 micrograms, a systematic review of 25 studies and 1,478 participants found longer sensory and motor blockade than placebo and a longer interval before the first request for rescue analgesia. However, transient bradycardia and hypotension were more frequent in that analysis. Other meta-analyses have differed in adverse-event estimates, reflecting variations in baseline hemodynamic risk, sample size, study protocols, and outcome ascertainment. Such results favor explicit safety monitoring and careful patient selection rather than a categorical statement that spinal dexmedetomidine is cardiovascularly risk free. [24,25]

Prolongation of sensory analgesia has two opposing implications for bladder recovery. Better pain control can reduce systemic opioid exposure and facilitate physiotherapy; prolonged sacral block can simultaneously postpone the return of filling sensation and coordinated voiding. Whether these competing effects produce a measurable difference in POUR depends on the surgical setting, spinal local anesthetic, timing of observation, and threshold for catheterization. This is more than a theoretical concern. In a randomized ambulatory knee-arthroscopy study using chloroprocaine, adding 5 micrograms of intrathecal dexmedetomidine delayed first voiding and discharge by approximately 40 minutes compared with the relevant comparator, while not increasing measured treatment for micturition difficulties. A delay in voiding is therefore not necessarily equivalent to a higher incidence of clinically defined retention. [26,27]

Comparative efficacy: the distinction between block duration and recovery

Direct comparisons of dexmedetomidine and fentanyl generally favor dexmedetomidine for the duration of sensory and motor blockade. In a randomized trial using 12.5 mg hyperbaric bupivacaine with either dexmedetomidine 5 micrograms or fentanyl 25 micrograms, Gupta and colleagues found substantially later sensory regression and motor recovery with dexmedetomidine, alongside a longer analgesic interval. This is an important pharmacodynamic comparison because the drug and local anesthetic doses resemble many lower-limb orthopedic research protocols. However, the trial was performed in lower abdominal surgery, and its principal outcomes were block characteristics rather than standardized bladder scanning or catheterization-defined POUR. Its findings therefore describe analgesic performance and recovery of somatic blockade, not a confirmed urinary advantage. [28,29]

An orthopedic-specific randomized study that compared hyperbaric bupivacaine with dexmedetomidine, fentanyl, or saline reported useful differences in onset and persistence of spinal blockade. The relevance of this three-arm design is that it distinguishes enhancement over local anesthetic alone from direct superiority between the two adjuvants. Yet the orthopedic label itself should not obscure endpoint selection: trials primarily designed for sensory regression and analgesic requirement may have too few urinary events to assess retention credibly. An apparently reassuring adverse-event table is not proof that no meaningful bladder effect exists if systematic ultrasound surveillance was not part of the protocol. For a urinary-focused review, adequacy of detection is a key element of trial quality. [30,31]

The pooled comparison of nine randomized trials involving 639 patients found longer sensory and motor block and pain-free periods with dexmedetomidine than with fentanyl, while pruritus was less frequent. Between-study heterogeneity was substantial for several efficacy outcomes, with I-squared values approaching 96–97%, cautioning against applying any single pooled duration to a specific orthopedic pathway. Although some reported adverse events were statistically similar, infrequent outcomes such as urinary retention are not adequately resolved by analyses emphasizing pain and block performance. Meta-analysis can improve precision only for outcomes consistently measured in the contributing studies; it cannot substitute for missing bladder data. [6,31]

A separate randomized comparison in lower abdominal surgery likewise reported longer postoperative analgesia with dexmedetomidine added to hyperbaric bupivacaine than with fentanyl. Investigations using lower doses of local anesthetic, different baricities, or different operative settings have generated somewhat different recovery patterns. Such heterogeneity is clinically expected: a sensory block optimized for a long abdominal procedure differs from one designed for rapid arthroscopic discharge. When comparing trials, the dose of bupivacaine, intrathecal adjuvant dose, injected volume, position, anticipated operation length, and definition of block regression should be reported before declaring any adjuvant generally superior. Urinary outcomes should remain a distinct domain rather than be inferred from the comparative analgesic hierarchy. [29,32]

Evidence directly addressing postoperative urinary retention

The most directly applicable head-to-head study evaluated intrathecal dexmedetomidine 5 micrograms versus



fentanyl 25 micrograms as adjuncts to low-dose bupivacaine during unilateral arthroscopic knee surgery. El-Saeid and colleagues observed urinary retention in 5.7% of the dexmedetomidine group compared with 20% of the fentanyl group, but the between-group difference did not meet conventional statistical significance ($P = .074$). The numerical direction is clinically interesting, yet the study does not establish that dexmedetomidine prevents POUR. Nor should it be described as showing a statistically proven protective effect. Precision, event counts, and the exact method of outcome ascertainment matter as much as a point estimate when a relatively uncommon complication is assessed in a modest-sized trial. [33]

This result also highlights the importance of checking the published study rather than relying on a secondary numerical quotation. The 28.6% fentanyl figure sometimes attributed to that study is not the urinary-retention percentage presented in the final article abstract; the reported comparator value is 20%. Even a small alteration in an outcome proportion can produce a misleading impression about effect magnitude, especially when a new clinical trial uses the earlier report for its sample-size assumptions. A review should provide the original observed proportions, recognize the nonsignificant inferential result, and avoid pooling incompatible measures. The proposed mechanistic explanation that dexmedetomidine necessarily preserves sacral parasympathetic output is also too strong for the available human data. [33,34]

The contrast between the bupivacaine head-to-head study and the chloroprocaine ambulatory trial is instructive rather than contradictory. One assesses a binary retention endpoint under a particular unilateral spinal protocol, while the other detects an approximately 40-minute difference in first voiding after intrathecal dexmedetomidine. Time to first void, postvoid residual urine, inability to void at a fixed postoperative hour, catheterization, and overdistension are not interchangeable endpoints. A patient may void later without ever needing catheterization; another may have a distended bladder with no urge and be catheterized before attempting micturition. Meaningful synthesis requires the complete outcome trajectory and careful attention to the temporal origin of each measurement. [26,33]

Measurement of POUR: diagnostic and methodological challenges

The definition of POUR is a central methodological problem. Some studies count any urinary catheterization, others require failure to void at a specified time, and others combine inability to void with a bladder-volume cutoff. These designs answer different questions. Catheterization is a management event influenced by local policy and therefore is an imperfect surrogate for biological urinary dysfunction. Ultrasound-measured bladder volume provides a more objective description, but the chosen measurement time, symptom status, and previous voiding attempts must be recorded. Researchers should distinguish first spontaneous micturition from first successful micturition with acceptable residual volume and distinguish temporary intermittent catheterization from prolonged indwelling catheterization. [3,11]

Ultrasonographic monitoring permits recognition of bladder filling before overdistension becomes clinically obvious. A structured protocol can schedule repeat scans at intervals informed by the estimated bladder volume and ongoing intravenous fluid input. The best intervention threshold, however, is not universal. In fast-track total hip and knee arthroplasty, a randomized comparison of catheterization thresholds of 500 and 800 mL demonstrated that choice of threshold changes the frequency of catheterization. A separate postanesthesia care unit cohort introduced an 800 mL threshold together with volume-dependent surveillance and found fewer catheterizations than a historical 400 mL protocol without an increase in later ward catheterization. Neither result supports ignoring symptoms or applying a high threshold to every patient regardless of risk. [35,36]

A practical study protocol might define its primary endpoint as inability to void with a sonographically measured bladder volume exceeding 600 mL at a predefined postoperative time. Such an operational definition has the advantage of clarity and reproducibility, but its limitations must be explicit: the four-hour cutoff may miss later retention, and patients catheterized earlier for symptoms cannot simply be grouped with those who void normally. A stronger design records bladder volume serially, documents whether patients experienced discomfort or urgency, reports all catheterization decisions, and considers the time from spinal injection separately from the time from completion of surgery. Investigators should prespecify an approach for patients discharged before the planned assessment and for those receiving prophylactic catheters. [3,35]

Bladder-volume thresholds have consequences for the apparent comparative effectiveness of the adjuvants themselves. For example, if dexmedetomidine lengthens spinal sensory regression, a patient assessed at the fourth postoperative hour may be unable to void but remain below a chosen 600 mL threshold. The same patient could be classified as having no retention despite later spontaneous voiding, while an identical patient given more fluid might cross the threshold and become a counted event. Differences in infused fluids, diuretics, patient size, and scan timing can therefore alter classification independently of pharmacology. Future trial reports should publish the distribution of postoperative bladder volumes and timing of voiding in addition to the binary primary endpoint. A sensitivity analysis applying more than one clinically justifiable threshold would indicate whether the reported effect



is robust or created largely by a particular definition. [3,35]

Clinical prevention and individualized management

Prevention begins before the spinal injection. A focused urinary history should ask about baseline voiding difficulty, nocturia, weak stream, incomplete emptying, previous retention, known prostate disease, and relevant neurological pathology. Avoiding unnecessary preoperative bladder filling is sensible, although aggressive fluid restriction solely to prevent retention can compromise hemodynamic care. Encouraging voluntary voiding before the patient enters the theater and documenting a baseline bladder volume may reduce ambiguity during recovery. In patients with substantial risk factors, clinicians should discuss expected surveillance and the possibility of temporary catheterization as part of informed perioperative planning. These measures are compatible with enhanced recovery but require local resources and a clear escalation pathway. [3,7]

Intraoperative prevention involves selecting a spinal technique whose anticipated duration fits the operation. The volume of crystalloid, use of sedatives, systemic opioids, postoperative pain burden, and the length of immobilization all require attention. Early mobilization and opioid-sparing strategies have supportive evidence across surgical populations, whereas drug prophylaxis requires more selective interpretation. Systematic reviews suggest benefits for alpha-adrenergic antagonists in certain settings, but arthroplasty trials have reported conflicting findings, and prophylaxis is not a replacement for recognition of significant bladder distension. A patient with hypotension or orthostatic vulnerability may incur added risk from a preventive alpha-blocker, especially when mobilization is a priority. [22,37,38]

After surgery, symptom assessment should be paired with objective bladder surveillance when regional block persists or when patients are unable to mobilize. A pain-free patient may have a large bladder without urgency, whereas suprapubic pain or agitation warrants prompt assessment even before an arbitrary routine scan is due. When the intervention threshold is reached, staff should facilitate safe voiding if possible, reassess within a defined interval, and use intermittent catheterization when clinically indicated. Persistent inability to void, recurrent high residual volume, or complex urological history should trigger individualized reassessment rather than repeated unstructured catheterization. Explicit handover between the postanesthesia care unit and ward is particularly important because urinary dysfunction can persist beyond recovery of motor strength. [11,35]

Avoiding routine indwelling urinary catheter placement is another component of appropriate stewardship, especially during uncomplicated arthroplasty. A meta-analysis of randomized trials found greater urinary tract infection risk with indwelling catheterization compared with no routine catheter, without a statistically established difference in retention frequency. A more recent randomized arthroplasty trial examined the use of a short-term intraoperative Foley catheter and likewise questioned routine placement solely as a preventive strategy. These data should not be interpreted as a reason to withhold catheterization when clinically indicated. The more defensible approach is to minimize unnecessary instrumentation, monitor patients in whom retention is likely, and intervene promptly if they become symptomatic or reach a prespecified safe limit. This approach is consistent with the broader principles of enhanced recovery after hip and knee replacement. [39,40,41]

Translating the evidence into adjuvant selection

For a healthy adult having a short knee arthroscopy, an adjuvant that provides satisfactory operative analgesia without substantially delaying mobility and voiding may be preferable to one that maximizes block duration. For more prolonged orthopedic surgery, the reduced need for systemic analgesics associated with dexmedetomidine may be attractive, provided cardiovascular monitoring and recovery time are acceptable. Neither profile justifies a blanket preference based on hypothetical urinary mechanisms. The clinically relevant comparison includes sufficient block duration, first analgesic request, rescue-opioid exposure, motor recovery, sacral sensory recovery, postoperative bladder volumes, catheterization, and discharge readiness. Decisions should therefore be framed as trade-offs rather than a ranking based on a single favorable endpoint. [6,26,33]

The route of dexmedetomidine administration is another important source of potential confusion. Intravenous dexmedetomidine during spinal anesthesia can prolong analgesic effects without the same direct intrathecal exposure. In a knee arthroplasty noninferiority trial using intravenous dexmedetomidine sedation, bupivacaine without intrathecal fentanyl achieved a noninferior sensory regression profile compared with bupivacaine plus fentanyl. This finding raises questions about whether intrathecal opioid addition is always necessary under such conditions, but it does not establish an equivalent urinary profile for intravenous and spinal dexmedetomidine. Reviews should consistently label administration route and avoid combining fundamentally different exposure strategies in a single undifferentiated conclusion. [42,43]

When considering postoperative recovery, the choice of local anesthetic may have a greater effect on the voiding trajectory than the choice of adjuvant alone. A systematic review comparing mepivacaine with bupivacaine in total joint arthroplasty reported earlier motor recovery and a lower frequency of urinary retention with mepivacaine-based



spinal anesthesia. Randomized knee-arthroscopy data likewise found earlier first voiding and discharge with chloroprocaine than with bupivacaine. These results do not prove that one short-acting agent is ideal for every procedure, and short-acting regimens can require additional postoperative analgesic planning. They do, however, illustrate the need to regard anesthetic duration as a modifiable component of recovery. Comparisons of dexmedetomidine and fentanyl conducted entirely on a fixed long-acting bupivacaine platform answer only one part of a broader optimization question. [44,45]

Limitations of the evidence and future priorities

The literature has several recurring limitations. Comparative trials are frequently small, and many were designed around rapid sensory regression or duration of analgesia rather than urinary events. Definitions of POUR differ, formal bladder scanning is inconsistently performed, and catheterization policies are often left to clinician discretion. Important predictors such as baseline urinary symptoms, sex-specific outflow disease, intraoperative fluid volume, and opioid exposure are not uniformly reported. Placebo-controlled evidence establishes that dexmedetomidine can prolong spinal block but does not answer the direct urinary question against fentanyl. In addition, meta-analyses may be statistically impressive for block duration while having low or very low certainty regarding less commonly reported safety outcomes. [6,24,46]

Future randomized trials should prespecify a clinically meaningful urinary endpoint, provide an event-based sample-size calculation, and enroll sufficient patients to assess that endpoint rather than relying on analgesic surrogates. Both arms should receive the same dose and baricity of bupivacaine and use standardized intravenous fluid, systemic analgesia, and urinary monitoring protocols. Blinded assessment, explicit definitions of catheterization, and intention-to-treat analyses would strengthen validity. Serial bladder measurements should start from the same time origin, with documentation of sacral regression, first desire to void, first spontaneous void, postvoid residual volume, and catheter duration. Reporting these observations as separate outcomes would clarify whether an adjuvant alters the biology of voiding or merely shifts the time of a routine nursing intervention. [3,22,33]

A useful multicenter study should include a priori subgroup analyses based on urinary symptom burden, age, operation type, and anticipated length of recovery, while avoiding underpowered conclusions from small subgroups. Patient-centered endpoints could include discomfort from overdistension, unscheduled hospitalization, catheter-associated complications, and satisfaction with voiding recovery. Follow-up after discharge is necessary for ambulatory surgery because retention may emerge when the spinal block has apparently resolved. Such investigations would make possible a clinically meaningful estimate of absolute benefit or harm: the number of additional patients experiencing delayed voiding or receiving a catheter per 100 treated, balanced against the additional duration of pain relief and possible reductions in systemic opioid consumption. [8,36,46]

Clinical interpretation also benefits from a balanced view of patient-centered outcomes. A patient who receives dexmedetomidine may be comfortable for longer after surgery yet require additional time before mobilization. Another patient receiving fentanyl may mobilize sooner but develop pruritus or require earlier systemic rescue analgesia. These profiles cannot be judged by a composite “success” measure unless its components are transparent and valued appropriately. A robust future comparison should report a hierarchy of outcomes: need for rescue conversion during surgery, clinically important bladder overdistension, catheterization, time to independent walking, pain burden over 24 hours, and unplanned admission. Health-economic analysis could then evaluate whether extra postoperative observation and bladder monitoring outweigh reductions in pain medication and nursing intervention. It is this multidimensional approach, rather than a simplistic drug ranking, that is most likely to improve orthopedic recovery. [6,33,47]

A final research priority is the distinction between pharmacological causation and temporal association. A drug that extends the spinal block may postpone the first observed void solely by extending recovery of sensory input, while a patient who remains immobile or has not been offered an appropriate voiding opportunity may experience an additional behavioral delay. Catheterization rates also reflect provider instructions and local resources. An informative trial would therefore pair serial sacral sensory tests and bladder scans with a standardized assisted-voiding opportunity once motor function permits. In parallel, postoperative pain, administered opioids, fluid balance, and hemodynamic events should be recorded as possible mediators or competing explanations. Such a dataset would clarify how adjuvant effects interact with bladder physiology without assuming that every delay in micturition represents a direct drug toxicity. [12,26,48]

Systemic alpha-adrenergic antagonists further demonstrate why context matters when interpreting pooled benefits. Meta-analyses spanning abdominal, pelvic, and orthopedic operations sometimes show an overall reduction in retention, but the orthopedic-only analysis of randomized evidence did not show a clear reduction and noted more adverse events such as dizziness or syncope. For patients recovering from hip or knee surgery, these effects can compromise early ambulation and interact with the hypotensive tendency of neuraxial blockade. Routine drug prophylaxis is therefore not an acceptable substitute for perioperative risk assessment and direct measurement of



bladder filling. Future studies should stratify by surgical category, baseline lower urinary tract symptoms, and concurrent anesthetic interventions so that results remain applicable to specific pathways rather than an unselected postoperative population. [37,38,49]

An additional concern is publication and reporting bias. Trials of neuraxial adjuvants frequently power their calculations for statistically sensitive outcomes such as minutes of sensory block regression, which require far fewer participants than clinically meaningful differences in a relatively uncommon retention event. An adverse-event table containing zero urinary events may mean that events were absent, that the population was low risk, or that the event was never measured with adequate surveillance. Prospective registration should therefore identify a primary bladder outcome and its assessment schedule. Reports should describe loss to follow-up, earlier-than-planned discharges, bladder protocols at the receiving ward, and any catheter placed for reasons unrelated to retention. A systematic synthesis restricted to studies with rigorous outcome capture would provide stronger evidence than an unrestricted pooling of heterogeneous adverse-event reports. [25,33,50]

Conclusion

Intrathecal dexmedetomidine and fentanyl enhance bupivacaine spinal anesthesia through different receptor systems, and dexmedetomidine generally provides more prolonged sensory and motor blockade. Current evidence does not establish that this analgesic advantage reliably lowers postoperative urinary retention. Bladder recovery depends on sacral neural regression, baseline urinary function, surgical and medication factors, and the diagnostic threshold used. Objective bladder surveillance and consistent outcome definitions are necessary for safe individualized care and for valid comparisons between neuraxial adjuvants.

References

- Baldini G, Bagry H, Aprikian A, Carli F. Postoperative urinary retention: anesthetic and perioperative considerations. *Anesthesiology*. 2009;110(5):1139-1157. PMID:19352147.
- Cambise C, De Cicco R, Luca E, et al. Postoperative urinary retention (POUR): a narrative review. *Saudi J Anaesth*. 2024;18(2):265-271. doi:10.4103/sja.sja_88_24.
- Jackson J, Davies P, Leggett N, et al. Systematic review of interventions for the prevention and treatment of postoperative urinary retention. *BJS Open*. 2019;3(1):11-23. doi:10.1002/bjs5.50114.
- Møller T, Engedal MS, Plum LM, Aasvang EK. Reduced need for urinary bladder catheterization in the postanesthesia care unit after implementation of an evidence-based protocol. *Eur Urol Open Sci*. 2021;26:27-34. doi:10.1016/j.euros.2021.01.013.
- Effects of dexmedetomidine, fentanyl and magnesium sulfate added to ropivacaine on sensory and motor blocks in lower abdominal surgery: a randomized clinical trial. 2024. PMID:39073337.
- Comparison of dexmedetomidine and fentanyl as local anesthetic adjuvants in spinal anesthesia: a systematic review and meta-analysis of randomized controlled trials. 2017. PMID:29238167.
- Bjerregaard LS, Bogø S, Raaschou S, et al. Incidence of and risk factors for postoperative urinary retention in fast-track hip and knee arthroplasty. *Acta Orthop*. 2015;86(2):183-188. doi:10.3109/17453674.2014.972262.
- Incidence and risk factors of postoperative urinary retention and bladder catheterization in patients undergoing fast-track total joint arthroplasty: a prospective observational study on 371 patients. *J Arthroplasty*. 2018. PMID:29306574.
- Reed LA, Mihas AK, Fortin TA, et al. Risk factors for postoperative urinary retention following lumbar spine surgery: a review of current literature and meta-analysis. *Global Spine J*. 2023;13(6):1658-1670. doi:10.1177/21925682221146493.
- Chang Y, Chi KY, Tai TW, et al. Risk factors for postoperative urinary retention following elective spine surgery: a meta-analysis. *Spine J*. 2021;21(11):1802-1811. doi:10.1016/j.spinee.2021.05.009.
- Choi S, Awad I. Maintaining micturition in the perioperative period: strategies to avoid urinary retention. *Curr Opin Anaesthesiol*. 2013;26(3):361-367.
- Fowler CJ, Griffiths D, de Groat WC. The neural control of micturition. *Nat Rev Neurosci*. 2008;9(6):453-466. doi:10.1038/nrn2401.
- de Groat WC, Yoshimura N. Anatomy and physiology of the lower urinary tract. *Handb Clin Neurol*. 2015;130:61-108. doi:10.1016/B978-0-444-63247-0.00005-5.
- Bladder function in spinal anaesthesia. *Acta Anaesthesiol Scand*. 1985. PMID:3993320.
- Recovery of storage and emptying functions of the urinary bladder after spinal anesthesia with lidocaine and with bupivacaine in men. *Anesthesiology*. 1998. PMID:9477049.
- Postoperative urinary retention: a controlled trial of fixed-dose spinal anesthesia using bupivacaine versus ropivacaine. 2020. PMID:32174666.
- Intrathecal fentanyl with small-dose dilute bupivacaine: better anesthesia without prolonging recovery. *Anesth Analg*. 1997. PMID:9296409.
- Voelckel WG, Kirchmair L, Rehder P, et al. Unilateral anesthesia does not affect the incidence of urinary retention after low-dose spinal anesthesia for knee surgery. *Anesth Analg*. 2009;109(3):986-987. doi:10.1213/ane.0b013e3181af406e.
- Intrathecal fentanyl added to intrathecal bupivacaine for day case surgery: a randomized study. 2003. PMID:12703834.
- Kamphuis ET, Kuipers PW, van Venrooij GE, Kalkman CJ. The effects of spinal anesthesia with lidocaine and sufentanil on lower urinary tract functions. *Anesth Analg*. 2008;107(6):2073-2078. doi:10.1213/ane.0b013e318187bc0e.
- Medical and non-medical interventions for post-operative urinary retention prevention: network meta-analysis and risk-benefit analysis. 2021. PMID:34211585.
- Gao B, Zhang D, Wang Y, Wang Z, Wang Z. The effect of tamsulosin in postoperative urinary retention: a meta-analysis of randomized controlled trials. *Naunyn Schmiedeberg's Arch Pharmacol*. 2023;396(3):441-451. doi:10.1007/s00210-022-02343-y.



23. Weerink MAS, Struys MMRF, Hannivoort LN, et al. Clinical pharmacokinetics and pharmacodynamics of dexmedetomidine. *Clin Pharmacokinet*. 2017;56(8):893-913. doi:10.1007/s40262-017-0507-7.
24. Liu S, Zhao P, Cui Y, et al. Effect of 5-µg dose of dexmedetomidine in combination with intrathecal bupivacaine on spinal anesthesia: a systematic review and meta-analysis. *Clin Ther*. 2020;42(4):676-690.e5. doi:10.1016/j.clinthera.2020.02.009.
25. A systematic review and meta-analysis of efficacy and safety of dexmedetomidine combined with intrathecal bupivacaine compared to placebo. 2023. PMID:36644042.
26. Spinal or intravenous dexmedetomidine for spinal anesthesia with chloroprocaine in ambulatory knee arthroscopies: a double-blind randomized trial. 2021. PMID:34849019.
27. Intrathecal dexmedetomidine and postoperative pain: a systematic review and meta-analysis of randomized controlled trials. 2020. PMID:32333825.
28. Gupta R, Verma R, Bogra J, Kohli M, Raman R, Kushwaha JK. A comparative study of intrathecal dexmedetomidine and fentanyl as adjuvants to bupivacaine. *J Anaesthesiol Clin Pharmacol*. 2011;27(3):339-343. doi:10.4103/0970-9185.83678.
29. A comparative study between intrathecal dexmedetomidine and fentanyl as adjuvant to intrathecal bupivacaine in lower abdominal surgeries: a randomized trial. 2015. PMID:26417118.
30. Comparative addition of dexmedetomidine and fentanyl to intrathecal bupivacaine in orthopedic procedure in lower limbs. 2018. PMID:29875020.
31. Effects of intravenous and intrathecal dexmedetomidine in spinal anesthesia: a meta-analysis. *CNS Neurosci Ther*. 2014. PMID:24118775.
32. A prospective randomised double blind study of intrathecal fentanyl and dexmedetomidine added to low dose bupivacaine for spinal anesthesia for lower abdominal surgeries. 2014. PMID:25197111.
33. El-Saeid GM, Bassiouny MA, Al Sharabasy TH, Abdelrahman TN. Dexmedetomidine versus fentanyl effect as adjuvants to bupivacaine on post spinal urinary retention in knee joint arthroscopic surgeries. *Egypt J Anaesth*. 2023;39(1):226-232. doi:10.1080/11101849.2023.2182995.
34. Investigating postoperative urinary retention: risk factors and postsurgical outcomes in total joint arthroplasty. 2024. PMID:39811771.
35. Bjerregaard LS, Hornum U, Trolborg C, et al. Postoperative urinary catheterization thresholds of 500 versus 800 ml after fast-track total hip and knee arthroplasty: a randomized, open-label, controlled trial. *Anesthesiology*. 2016;124(6):1256-1264. doi:10.1097/ALN.0000000000001112.
36. Spinal anaesthesia with chloroprocaine 1% versus total intravenous anaesthesia for outpatient knee arthroscopy: a randomised controlled trial. 2018. PMID:29521661.
37. Preventive effects of tamsulosin for postoperative urinary retention after lower limb arthroplasty: a randomized controlled study. 2021. PMID:34387038.
38. The AAHKS clinical research award: prophylactic tamsulosin does not reduce the risk of urinary retention following lower extremity arthroplasty: a double-blinded randomized controlled trial. 2019. PMID:30982761.
39. Indwelling catheter can increase postoperative urinary tract infection and may not be required in total joint arthroplasty: a meta-analysis of randomized controlled trial. 2019. PMID:30611266.
40. Weintraub MT, et al. Short-term indwelling Foley catheters do not reduce the risk of postoperative urinary retention in uncomplicated primary THA and TKA: a randomized controlled trial. *J Bone Joint Surg Am*. 2023. PMID:36729534.
41. Wainwright TW, Gill M, McDonald DA, et al. Consensus statement for perioperative care in total hip replacement and total knee replacement surgery: Enhanced Recovery After Surgery Society recommendations. *Acta Orthop*. 2020;91(1):3-19. doi:10.1080/17453674.2019.1683790.
42. Park SK, Lee JH, Yoo S, et al. Comparison of bupivacaine plus intrathecal fentanyl and bupivacaine alone for spinal anesthesia with intravenous dexmedetomidine sedation: a randomized, double-blind, noninferiority trial. *Reg Anesth Pain Med*. 2019;44(4):459-465. doi:10.1136/rapm-2018-100084.
43. Lee SC, Kim TH, Choi SR, Park SY. No difference between spinal anesthesia with hyperbaric ropivacaine and intravenous dexmedetomidine sedation with and without intrathecal fentanyl: a randomized noninferiority trial. *Pain Res Manag*. 2022;2022:3395783. doi:10.1155/2022/3395783.
44. Mepivacaine versus bupivacaine spinal anesthesia for primary total joint arthroplasty: a systematic review and meta-analysis. 2022. PMID:35306162.
45. Comparison of 2-chloroprocaine, bupivacaine, and lidocaine for spinal anesthesia in patients undergoing knee arthroscopy in an outpatient setting: a double-blind randomized controlled trial. 2016. PMID:27281722.
46. Risk factors of postoperative urinary retention following total hip and knee arthroplasty. 2024. PMID:39022904.
47. Baysden M, Hein D, Castillo S. Tamsulosin for prevention of postoperative urinary retention: a systematic review and meta-analysis. *Am J Health Syst Pharm*. 2023;80(6):373-383. doi:10.1093/ajhp/zxac349.
48. Zhou Z, Gan W, Li Z, et al. Can prophylactic tamsulosin reduce the risk of urinary retention after surgery? A systematic review and meta-analysis of randomized control trials. *Int J Surg*. 2023;109(3):438-448. doi:10.1097/JS9.0000000000000267.
49. Impact of perioperative alpha1-antagonists on postoperative urinary retention in orthopaedic surgery: meta-analysis. 2023. PMID:36611262.
50. Chloroprocaine provides safe, effective, short-acting spinal anesthesia ideal for ambulatory surgeries: a retrospective review. 2020. PMID:33380957.