*British Journal of Anaesthesia* **110** (4): 518–28 (2013)
Advance Access publication 24 February 2013 · doi:10.1093/bja/aet013

BJA

# Falls and major orthopaedic surgery with peripheral nerve blockade: a systematic review and meta-analysis

R. L. Johnson[1]*, S. L. Kopp[1], J. R. Hebl[1], P. J. Erwin[2] and C. B. Mantilla[1]

[1] Department of Anesthesiology and [2] Department of Medical Education, College of Medicine, Mayo Clinic, 200 First Street, S.W., Rochester, MN 55905, USA

* Corresponding author. E-mail: johnson.rebecca1@mayo.edu

## Editor's key points

- The authors aimed to review an important issue of the risk of postoperative falls after peripheral nerve block.
- Only five studies qualified for meta-analysis; the patients had received lumbar plexus block or not.
- Continuous lumbar plexus block increased the risk of falls compared with non-continuous block or no block.
- The review, albeit involving a small number of studies, raises an important issue worthy of further research.

**Summary.** The objective of this systematic review with meta-analysis was to determine the risk for falls after major orthopaedic surgery with peripheral nerve blockade. Electronic databases from inception through January 2012 were searched. Eligible studies evaluated falls after peripheral nerve blockade in adult patients undergoing major lower extremity orthopaedic surgery. Independent reviewers working in duplicate extracted study characteristics, validity, and outcomes data. The Peto odds ratio (OR) with 95% confidence intervals (CIs) were estimated from each study that compared continuous lumbar plexus blockade with non-continuous blockade or no blockade using a fixed effects model. Ten studies (4014 patients) evaluated the number of falls as an outcome. Five studies did not contain comparison groups. The meta-analysis of five studies [four randomized controlled trials (RCTs) and one cohort] compared continuous lumbar plexus blockade (631 patients) with non-continuous blockade or no blockade (964 patients). Fourteen falls occurred in the continuous lumbar plexus block group when compared with five falls within the non-continuous block or no block group (attributable risk 1.7%; number needed to harm 59). Continuous lumbar plexus blockade was associated with a statistically significant increase in the risk for falls [Peto OR 3.85; 95% CI (1.52, 9.72); $P=0.005$; $I^2=0\%$]. Evidence was low (cohort) to high (RCTs) quality. Continuous lumbar plexus blockade in adult patients undergoing major lower extremity orthopaedic surgery increases the risk for postoperative falls compared with non-continuous blockade or no blockade. However, attributable risk was not outside the expected probability of postoperative falls after orthopaedic surgery.

**Keywords:** accidental falls; anaesthesia, conduction; arthroplasty, replacement, hip; arthroplasty, replacement, knee; muscle weakness; nerve block

Major lower extremity joint arthroplasties are common orthopaedic procedures requiring aggressive postoperative pain management to achieve successful functional outcomes such as participation in early physical therapy.[1 2] Peripheral nerve blockade has been shown to decrease hospital length of stay and provide superior pain control with fewer side-effects compared with epidural regional anaesthesia or patient-controlled i.v. opioid therapy.[3] However, there is controversy as to whether the benefits of peripheral nerve blockade come at the price of increasing the risk for postoperative falls.[3–11]

Falls in hospitalized patients are the focus of increasing attention. Postoperative falls can occur in as many as 1.6% of hospitalized surgical patients.[12] In 2008, the Centers for Medicare and Medicaid services included falls in the list of hospital-acquired conditions. Thus, if a fall occurs during an admission that hospital may not receive additional reimbursement for fall-associated costs.[13]

Falls may occur after orthopaedic surgery regardless of the presence of peripheral nerve blockade. Yet, prolonged quadriceps weakness resulting from lumbar plexus blockade may contribute to an increased fall risk.[6] The role of peripheral nerve blockade on postoperative fall risk has not been systematically studied. Furthermore, this specific clinical question has never been rigorously reviewed after a premeditated, transparent scientific methodology that allows the most valid analysis of the available literature. The aim of this systematic review with meta-analysis will be to advance our knowledge of falls occurring among patients who have undergone major orthopaedic lower extremity surgery with and without the presence of peripheral nerve blockade through quantitative and qualitative analysis of all available evidence.

## Methods

A protocol-driven systematic review addressing the intervention peripheral nerve blockade in adult patients undergoing major orthopaedic lower extremity surgery adhered to the

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[14]

## Eligibility criteria

Eligible studies were comparative studies, either randomized or observational, enrolling adult patients undergoing major orthopaedic lower extremity surgery who received peripheral nerve blockade. Included studies evaluated falls as an outcome. Major orthopaedic surgeries included total hip arthroplasty, total knee arthroplasty, and anterior cruciate ligament reconstruction. Studies included patients receiving peripheral nerve blockade via single injection, non-continuous blockade (catheter bolus with no greater than 24 h of infusion), continuous blockade (catheter infusions >24 h), or no nerve block. Peripheral nerve blockade for lower extremity surgery included lumbar plexus blockade via either psoas compartment block or femoral nerve block distal to the inguinal ligament, and any approach to proximal sciatic nerve blockade. All eligible studies were included regardless of size, language constraints, or quality assessment ratings. Strictly descriptive articles (e.g. reviews, commentaries or letters) were excluded.

## Study identification

An electronic search strategy specialist with expertise in conducting systematic reviews (P.J.E.) and content expert investigators conducted an electronic search through Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, Thompson Reuters Web of Science, and the Cochrane Central Register of Controlled Trials from database inception through January 2012. The search cross-referenced keywords including: Arthroplasty, Replacement, Hip; Arthroplasty, Replacement, Knee; hip prosthesis/or knee prosthesis; Anaesthesia, Conduction and/or Nerve Block; Muscle weakness and/or Muscle Hypotonia; Accidental Falls and/or falls; Nerve Block; Postoperative complications; and Humans. A revised search yielded 59 new abstracts not retrieved in the original search strategy based on two articles as benchmarks with keywords focusing on the delivery mechanism (peripheral nerve catheter) rather than nerve block.[4 11] A summary of the search strategies is available as Appendix. Additional studies were identified by review of the reference sections of all eligible studies and solicitation from content experts. Unpublished data were requested from authors of randomized controlled trials (RCTs) where the comparison groups included peripheral nerve blockade. Only original studies were used for data collection.

Candidacy was based on independent review of each of the abstracts by two study investigators (R.L.J. and C.B.M.). Eligibility of potential candidate studies (as determined by either reviewer) underwent full-text review by the two reviewers working independently and in duplicate. The reviewers calibrated their judgements. Disagreements were harmonized by consensus. Agreement was measured using $\kappa$-statistics.

## Data collection

Two reviewers (S.L.K. and R.L.J.) working independently and using replicate electronic data collection tools extracted all data from the full-text versions of eligible studies. Study characteristics included author, publication year, sample size, study population (age), type of major lower extremity surgery, intervention, study design, primary anaesthetic type, patient fall outcome data, and outcome data on falls resulting in death or serious disability. To evaluate falls, the number of patient falls was considered as the event (outcome of interest) rather than the absolute number of falls. Discrepancies in data collection were resolved by consensus first, followed by verification by a third co-investigator (C.B.M.) not involved with the data extraction process. Data that could not be extracted were listed as not reported (NR). Attempts were made to decrease the effect of reporting bias by requesting missing data and data inconsistency explanations by methodically contacting the authors of included studies.

Study quality was independently assessed by two reviewers (R.L.J. and S.L.K.). The Cochrane Collaboration Risk Assessment Tool[15] was used to evaluate the risk of bias for RCT evidence. The loss to follow-up, intention to treat, and imbalances at baseline were also assessed on included RCTs. The Newcastle–Ottawa quality assessment tool[16] was used to evaluate quality of observational studies; no scoring system was derived for this tool.

## Statistical analysis

A qualitative synthesis was performed for studies that reported data not comparable by formal meta-analysis. Meta-analysis used a fixed effects model to pool dichotomous variables. The Peto odds ratios (ORs) and 95% confidence intervals (CIs) were calculated among studies which evaluated continuous lumbar plexus blockade compared with non-continuous blockade or no block. Data analysis abided by the guidelines set out by the Cochrane Collaboration regarding statistical methods.[17] OR values of >1.00 were associated with an increased risk for fall. In all cases, two-tailed *P*-values of <0.05 were considered significant. The number needed to harm (NNH) was calculated as the inverse of attributable risk. Statistical heterogeneity of the data was quantified using $I^2$ statistic which estimates the percentage of total variation across studies that is not attributed to chance.[18 19] $I^2$ values of <25% represent low heterogeneity. Forest plots were used to show point estimates and CI of individual included studies. Publication bias was assessed using funnel plots. Sensitivity analyses were performed on the results of the meta-analyses by: (i) using a random effects model, (ii) including eligible retrospective data, and (iii) removing individual study data, one at a time. All statistical analyses were conducted using Review Manager [RevMan (Computer program), Version 5.1. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2011].

## Results

### Retrieved trials

In total, 10 studies (4014 patients; weighted-mean age: 52.7 yr) published between 2002 and 2011 met inclusion criteria by examining postoperative falls as an outcome during the use of peripheral nerve blockade (median study size: 83 patients).[3–5 8 10 20–24] The $\kappa$-statistic for reviewer agreement on study selection (0.78) indicated a substantial degree of agreement beyond chance.[25]

Figure 1 shows the process of study selection. After screening, 48 full-text articles were assessed for eligibility; all but four studies were excluded. Additionally, six studies were eligible after reference section reviews. Unpublished data were requested from three authors of papers which met population and intervention criteria but did not report fall data in the original publication.[26–28] After multiple contacts, none of these authors responded; thus, these studies were excluded.

### Study characteristics

Table 1 presents the description of study characteristics. Seven studies were RCTs;[3 5 20–24] three were cohort studies (one retrospective).[4 8 10] Only one prospective study directly compared patients with peripheral nerve blockade (regardless of duration) with those without peripheral nerve blockade.[10] Otherwise, included studies compared either different techniques for lumbar plexus blockade or different durations of local anaesthetic infusion via peripheral nerve catheters. No study reported confounders of falls such as medication use (e.g. anti-psychotics, sleeping aids, anti-epileptics), pre-existing weakness, or immobilizer use. Overall, no falls discovered in this analysis resulted in death or serious disability.

The studies included a number of major lower extremity orthopaedic procedures and various approaches to peripheral nerve blockade. Three investigations examined total hip arthroplasty (all with continuous lumbar plexus blockade at the psoas compartment),[5 21 22] and five studied total knee arthroplasty (all with lumbar plexus blockade at the femoral level, four via continuous blockade [3 4 20 24] and one using a single-injection technique).[10] One of these total knee arthroplasty studies, an RCT, investigated adding no sciatic blockade, single-injection sciatic blockade, or continuous sciatic blockade to lumbar plexus blockade at the femoral level.[24] One study investigated anterior cruciate ligament repair under continuous lumbar plexus blockade.[23] The remaining study investigated both upper and lower extremity ambulatory surgeries (without further detail) with peripheral nerve blockade using single-injection techniques.[8] Of the 10 included studies, all reported the use of nerve stimulation for peripheral nerve blockade, but two also reported using a combined ultrasound and nerve stimulation localization technique.[21 24]

### Study quality

All of the included RCTs[3 5 20–24] were of high quality (Table 2) based on the criteria from the Cochrane 'Risk of Bias' assessment tool.[15] There were no important imbalances at baseline in each study. All were reportedly analysed by intention-to-treat. However, one patient was excluded from the analysis of fall risk after randomization and intervention in one RCT.[3] None of the RCTs reported loss to follow-up.

Table 3 represents the quality of the three cohort studies,[4 8 10] as determined using the Newcastle–Ottawa assessment scale.[16] All three cohort studies were of low quality.

Inter-reviewer agreement on the evaluation of the different elements of study quality was assessed using the $\kappa$-statistic.[25] $\kappa$-Statistic was 0.88, which indicates an almost perfect degree of agreement beyond chance.

### Qualitative analysis

Of the 10 studies examining postoperative falls as an outcome during the use of peripheral nerve blockade, five studies (2419 patients) were not pooled into the meta-analysis because they examined minor variations in peripheral nerve blockade (e.g. two different infusion rates or approaches to the lumbar plexus),[21 22] did not include a no blockade (control) group,[24] or did not study a continuous lumbar plexus blockade group.[8 10]

Studies not pooled into the meta-analysis included three RCTs[21 22 24] and two cohort studies.[8 10] Four falls were reported in one RCT including 89 patients.[24] These falls occurred on postoperative day 2 and were attributed to violations in study safety instructions, prompting the authors to reinforce nurse and patient education on postoperative fall risk. There were no falls reported in the remaining two RCTs (97 patients).[21 22]

Fourteen falls occurred in the two cohort studies (2233 patients).[8 10] Overall, three falls occurred within 24 h of surgery, five on postoperative day 1, and six on or after postoperative day 2. Thirteen falls occurred in 1992 patients after single-injection blocks (0.7% fall frequency), while one occurred in 241 patients without nerve blockade (0.4% fall frequency). Four falls occurred in patients with delirium or confusion, only one of which was in the group without peripheral nerve blockade.

### Meta-analysis

Five studies compared continuous lumbar plexus catheter blockade (631 patients) with non-continuous blockade or no blockade (964 patients).[3–5 20 23] We successfully contacted the author of three of the five included studies to confirm data collection.[3 5 20] Fourteen falls occurred in 631 patients in the continuous lumbar plexus blockade group (2.2%) compared with five falls in 964 patients in the non-continuous block or no block group (0.5%). Continuous lumbar plexus catheter blockade was associated with a statistically significant increase in the risk for falls [Fig. 2; Peto OR 3.85; 95% CI (1.52, 9.72)]. Low heterogeneity was evident by $I^2$=0%. The attributable risk of patient falls among

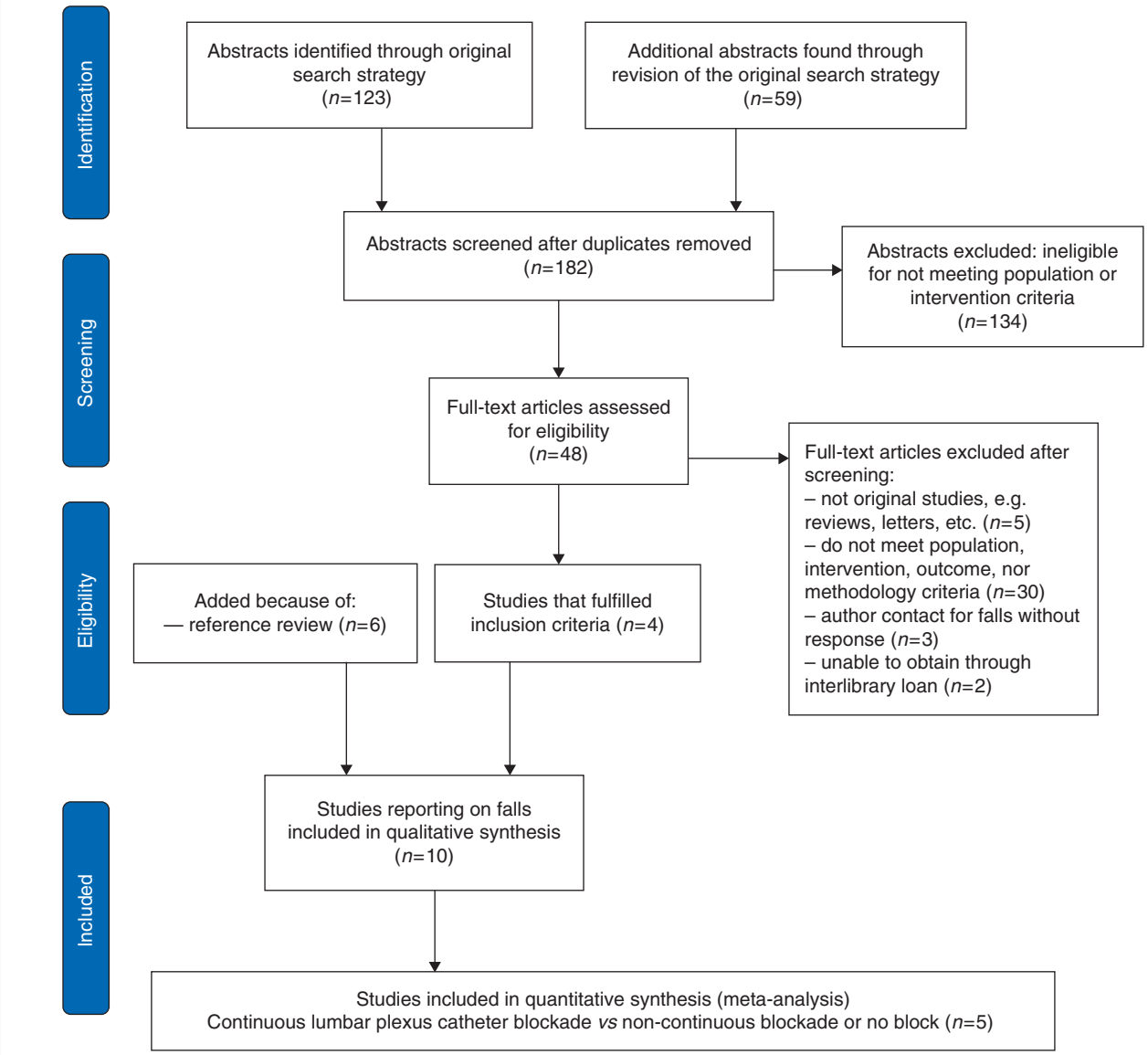


**Fig 1** Flow diagram of study selection. Flow diagram adapted based on PRISMA statement.[14]

lower extremity orthopaedic patients receiving continuous lumbar plexus blockade compared with non-continuous blockade or no block was 1.7%, resulting in an NNH of 59.

Only limited information was available regarding possible confounding factors. One fall in the continuous lumbar plexus blockade was associated with evidence of quadriceps muscle weakness. Eight falls in the non-continuous blockade group occurred during times of documented quadriceps muscle weakness. No study reported quadriceps muscle weakness in patients who did not fall, thus it was not possible to test for a possible interaction between quadriceps weakness and falls. Meta-regression for the type of peripheral nerve block was also not possible, considering the limited number of patients in each subgroup.

### Sensitivity analysis

A single retrospective study of low quality contributed to 42.5% of the weight of meta-analysis.[4] Although this retrospective study of low quality contributes to methodological heterogeneity, the Peto OR changed only minimally after study exclusion [Peto OR 7.43, 95% CI (2.19, 25.26), $P=0.001$], and the overall results are not altered. Serial exclusion of the remaining four RCTs also did not meaningfully change the overall results.

## Discussion

This systematic review and meta-analysis reports a statistically significant increased risk for falls in patients undergoing major orthopaedic surgery with continuous lumbar plexus

**Table 1** Study characteristics. *All peripheral nerve blocks (PNB) were placed using nerve stimulation. †All patients received continuous femoral nerve blockade and were randomized to receive no sciatic block, a single sciatic nerve block, or continuous sciatic nerve blockade via parasacral approach. ‡Patients were randomized to receive a bolus/infusion of local anaesthetic or saline. RCT, randomized controlled trial; NR, not reported; THA, total hip arthroplasty; TKA, total knee arthroplasty

| Study | Study design | Patients (#) | Age (mean) | Falls (#) | Surgical procedure | PNB* | Local anaesthetic | Infusion rate (ml $h^{-1}$) | Infusion duration (days) | Primary outcome | Secondary outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wegener and colleagues[24] | RCT | 29 | 62 | 0 | TKA | Femoral | Levo. 0.375%/ 0.125%† | 10 | 2 | Time-to-discharge readiness | Adverse effects including falls |
| | | 30 | 65 | 3 | TKA | Femoral+sciatic | Levo. 0.375%/ 0.125%+Levo. 0.375%† | 10 | 2 | | |
| | | 30 | 66 | 1 | TKA | Femoral+cont. sciatic | Levo. 0.375%/ 0.125%+Levo. 0.375%/0.125%† | 10+10 | 2 | | |
| Ilfeld and colleagues[21] | RCT | 22 | 57 | 0 | THA | Psoas | Ropiv. 0.2% | 6 | 2 | Pain scores | Adverse events including falls |
| | | 25 | 55 | 0 | THA | Femoral | Ropiv. 0.2% | 6 | 2 | | |
| Ilfeld and colleagues[22] | RCT | 26 | 69 | 0 | THA | Psoas | Ropiv. 0.1% | 12 | 2 | Maximum voluntary isometric contraction | Adverse events including falls |
| | | 24 | 68 | 0 | THA | Psoas | Ropiv. 0.4% | 3 | 2 | | |
| Ilfeld and colleagues[20] | RCT | 39 | 53 | 3 | TKA | Femoral | Ropiv. 0.2% | 6 | 4 | Time to discharge criteria | Adverse events including falls |
| | | 38 | 52 | 0 | TKA | Femoral | Ropiv. 0.2% | 6 | 1 | | |
| Sharma and colleagues[10] | Cohort | 729 | 53 | 12 | TKA | Femoral | Ropiv. 0.5% or | NA | No infusion | Adverse events including falls | |
| | | 241 | 52 | 1 | TKA | None | Bupiv. 0.5% | NA | | | |
| Feibel and colleagues[4] | Cohort | 469 | NR | 4 | TKA | Femoral | Ropiv. 0.5% | 2–3 | 2–3 | Adverse events including falls | |
| | | 721 | NR | 4 | TKA | Femoral | Ropiv. 0.5% | 2–3 | 12 h | | |
| Ilfeld and colleagues[3] | RCT | 25 | 66 | 1 | TKA | Femoral | Ropiv. 0.2% | 8 | 4 | Time to attain discharge criteria | Pain scores, ambulation (distance), opioid use |
| | | 25 | 64 | 0 | TKA | Femoral | Ropiv. 0.2% | 8 | 1 | | |
| Ilfeld and colleagues[5] | RCT | 24 | 57 | 3 | THA | Psoas | Ropiv. 0.2% | 8 | 4 | Ambulation distance and time to discharge | Max. passive hip flexion, resting and dynamic pain scores, opioid use, sleep disturbance, patient satisfaction |
| | | 23 | 59 | 0 | THA | Psoas | Ropiv. 0.2% | 8 | 1 | | |
| Williams and colleagues[23] | RCT | 78 | 28 | 0 | Anterior cruciate | Femoral | Saline/saline‡ | 5 | 2 | Pain scores | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 79 | 28 | 1 | | Femoral | Levobupiv. 0.25%/ saline‡ | 5 | 2 | | |
| | | 76 | 27 | 3 | Ligament repair | Femoral | Levobupiv. 0.25%/ Levobupiv. 0.25%‡ | 5 | 2 | | |
| Klein and colleagues[8] | Cohort | 338 | 55 | 0 | Upper and lower extremity | Psoas | Ropiv. 0.5% | NA | No infusion | Efficacy and pain scores | Adverse events including falls |
| | | 263 | 41 | 1 | | Femoral | Ropiv. 0.5% | NA | | | |
| | | 662 | 37 | 1 | | Sciatic | Ropiv. 0.5% | NA | | | |

blockade compared with those with non-continuous blockade or no blockade. This review represents the only comprehensive systematic review on this clinically relevant topic. Although all postsurgical patients are in danger of falling, our results indicate that continuous peripheral nerve blockade may increase the frequency of falls. However, eliminating continuous peripheral nerve blockade is unlikely to eliminate all falls and may negatively affect postoperative pain management, rehabilitation, and length of hospital stay.

Fall frequencies reported in this systematic review do not represent a substantial deviation from the expected number of falls in hospitalized patients. In contrast to a reported fall frequency of 1.6% in all hospitalized surgical patients, Kandasami and colleagues[7] reported a higher fall rate of 2% specifically among patients undergoing total knee arthroplasty with femoral nerve blockade.[12 29 30] Based on the results of our systematic review, continuous lumbar plexus blockade results in a four times greater relative risk of fall compared with non-continuous or no blockade. However, when evaluating continuous peripheral nerve blockade in isolation, the attributable risk is 0.7–1.7% with an NNH of 59–193. In other words, one out of every 59 individuals exposed to continuous lumbar plexus blockade during major lower extremity orthopaedic surgery will fall that would have otherwise not fallen. Hence, the risk should be weighed against the benefits of patient comfort, satisfaction, and functional outcomes improved through the use of continuous peripheral nerve blockade. To put this NNH value of 59 into context, a Cochrane review comparing epidural analgesia with systemic opioid or spinal anaesthesia for postoperative analgesia after hip or knee replacement reported an NNH of $<10$ for all primary outcomes of sedation, itching, urinary retention, and hypotension.[31] In fact, one out of 4.5 patients exposed to epidural analgesia will experience urinary retention. Despite this risk of harm, epidural analgesia has been proven to be effective for postoperative pain management after major joint replacement surgery.[32 33] In addition, not only is the NNH for epidural analgesia outcomes lower than that for falls in patients with continuous lower extremity peripheral nerve blockade, postoperative epidural analgesia is inferior to lumbar plexus blockade in comparative studies.[3 32]

Previous studies suggest that continuous lumbar plexus blockade may increase the rate of postoperative falls in patients undergoing major orthopaedic surgery.[3–8 11] A retrospective review[6] examined the risk of postoperative falls in patients with continuous lumbar plexus blockade by pooling data from three previously published RCTs on discharge readiness at a single institution.[3 5 20] This pooled analysis similarly reported an increased number of falls among a smaller sample of patients undergoing major orthopaedic surgery with continuous lower extremity peripheral nerve blockade and ultimately concluded that there was a causal relationship. Unfortunately, none of the above RCTs was designed to examine falls or fall risk as a primary outcome; furthermore, retrospective analysis restricts claims of cause

**Table 2** RCTs quality ratings. Quality of RCTs was determined using the Cochrane Risk of Bias Assessment Tool,[15] which evaluates the risk of bias in each category as unclear, low, or high. *Reported as intention-to-treat, but one patient withdrew after intervention and was excluded from the analysis of fall risk

| | Wegener and colleagues[24] | Ilfeld and colleagues[21] | Ilfeld and colleagues[22] | Ilfeld and colleagues[20] | Ilfeld and colleagues[3] | Ilfeld and colleagues[5] | Williams and colleagues[23] |
|---|---|---|---|---|---|---|---|
| Sequence generation | Low | Low | Low | Low | Low | Low | Low |
| Allocation concealment | Low | Unclear | Low | Low | Low | Low | Low |
| Blinding of participants | High | High | Low | Low | Low | Low | Low |
| Blinding of outcome | Unclear | Unclear | Low | Low | Low | Low | Low |
| Incomplete data | Low | Low | Low | Low | Low | Low | Low |
| Selective reporting | Low | Low | Low | Low | Low | Low | Low |
| Imbalances at baseline | No | No | No | No | No | No | No |
| Analysis by intention to treat | Yes | Yes | Yes | Yes | Yes* | Yes | Yes |
| Loss to follow-up | No | No | No | No | No | No | No |

**Table 3** Cohort study quality rating. Quality of cohort studies was determined using the Newcastle–Ottawa scale,[16] which evaluates three categories: selection (max. 4 stars), comparability (max. 2 stars), and outcome (max. 3 stars)

| Author | Year | Selection | Comparability | Outcome |
|---|---|---|---|---|
| Sharma and colleagues[10] | 2010 | **** | — | *** |
| Feibel and colleagues[4] | 2009 | *** | — | * |
| Klein and colleagues[8] | 2002 | *** | — | *** |

and effect associations. In contrast to the pooled analysis, this current systematic review includes eight times as many patients, and presents validity data on the quality of all included studies. Systematic reviews are a more scientific method of summarizing the literature with a goal of minimizing biases and summarizing data.[17] Although our systematic review results establishes an association between the use of continuous lumbar plexus nerve blockade and the risk of falling, the data indicate that the increased risk from continuous peripheral nerve blockade alone is not higher than the expected rate of falling among all patients undergoing major orthopaedic surgery. No specific information regarding the return of sensory and motor function after lower extremity peripheral nerve blockade was published in any of the 10 included studies and thus claims of a causal relationship between residual quadriceps muscle weakness from peripheral nerve blockade and number of patient falls are suspect. Accordingly, we did not test for interaction between quadriceps weakness and falls in the meta-analysis. Without controlling for other known confounders of postoperative falls (e.g. previous history of falls, postoperative delirium, use of sedatives or sleep aids, gabapentin use, and/or lack of use of immobilizers), peripheral nerve blockade and resulting quadriceps weakness cannot be proven to cause the reported increased risk of falls.[34–36]

The time of the fall may provide insight into why patients with continuous peripheral nerve blockade have an increased risk of falling after major orthopaedic surgery. Previous studies have established that patients are most vulnerable to falling within the first 48 h after peripheral nerve blockade.[3 5 9–11 37] Among the prospective observational studies and RCTs reporting temporality to postoperative falls, a majority of falls occur on postoperative day 2 or later. This is surprising because the sensorimotor block characteristic of a peripheral nerve block would be present in both an intervention group (continuous lumbar plexus blockade) and a control group (non-continuous lumbar plexus blockade) during the first 24 h, placing both single injection and continuous catheter groups at a similar risk of falling in the early postoperative period (<2 days postoperative days). Alternatively, bed restriction policies or increased nursing attention in the first 24 h may limit opportunities to fall. The fact that many falls occur on or after postoperative day 2 may suggest that other risk factors need to be considered other than the sensorimotor block caused by peripheral nerve blockade. These potential risk factors may include delirium, medication side-effects, reduced vigilance by patients and medical staff, walking without supervision, strength deficits in the surgical limb, and history of preoperative falls.[36 38]

Fall prevention strategies may make a difference in reducing the risk of patient falls in the postoperative period. One RCT reporting four postoperative falls during mobilization on

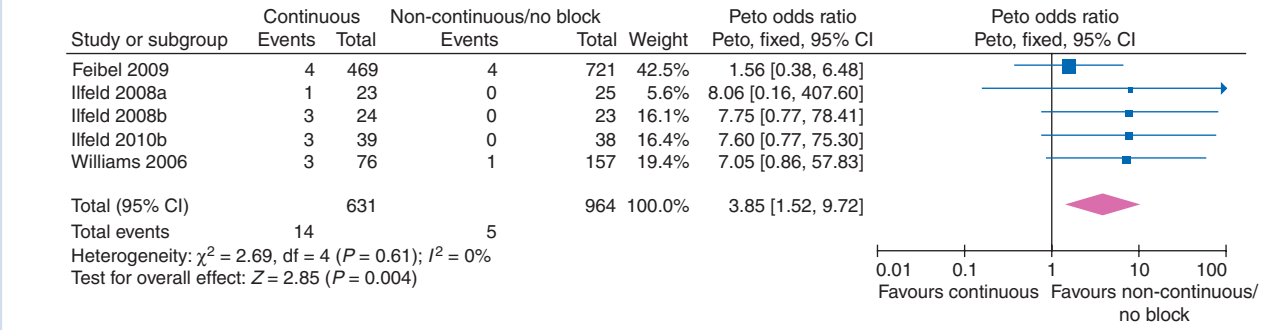


**Fig 2** Forest plot comparison of continuous lumbar plexus blockade *vs* non-continuous blockade or no block.

postoperative day 2 linked the falls to a violation of postoperative safety instruction and ambulation without supervision.[24] After repeated patient and nursing education about peripheral nerve block-induced muscle weakness and the risk of falling, no subsequent falls occurred within the study period. In addition to caregiver vigilance, knee bracing and the use of assistive devices have been shown to improve patient stability.[9]

### Limitations

Systematic reviews are retrospective in design and inherently limited by available literature. We enlisted a librarian with extensive experience with systematic reviews to identify the greatest number of relevant articles, sought clarification of published reports, and solicited unpublished data on the subject. However, it is possible that our protocol may have missed eligible studies, our inclusion criteria could have been too narrow, or exclusion of articles may have affected our results. Additionally, there is potential for underreporting of falls because minor events are often not recorded in the medical record.

We limited the meta-analysis to five of the nine eligible studies. These studies were similar enough to quantify an overall treatment effect by providing a direct comparison group between continuous and non-continuous blockade or no peripheral nerve blockade. This systemic review includes more than 4000 patients, and although it represents the largest review to date, we do call for future prospective studies. With the absence of prospective study data directly evaluating the risk of falls in patients with peripheral nerve blockade compared with no blockade and with no published evidence evaluating falls as a primary outcome, this was the best meta-analysis possible to limit heterogeneity and estimate the overall effect size of available evidence.

In conclusion, continuous lumbar plexus blockade in adult patients undergoing major lower extremity orthopaedic surgery is associated with an increased risk for postoperative falls compared with non-continuous blockade or no blockade. However, the attributable risk for falls was not outside the expected probability of postoperative falls among patients undergoing orthopaedic surgery. Future studies should directly compare continuous lumbar plexus blockade with sham blockade or no blockade. Additionally, studies should be designed to control for known risk factors for falls and evaluate the role of multimodal analgesia with and without lower extremity peripheral nerve blockade has not only on postoperative analgesia, but also quadriceps muscle strength, postoperative falls, and functional outcomes after major lower extremity orthopaedic surgery.

## Acknowledgements

We are grateful for the systematic review expertise including statistical support of Drs Colin P. West, M. Hassan Murad, and Victor M. Montori, course faculty for Systematic Reviews and Meta-Analyses, Mayo School of Graduate Medical Education.

## Declaration of interest

None declared.

## Funding

This publication was made possible by CTSA Grant Number UL1 TR000135 from the National Center for Advancing Translational Sciences (NCATS), a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIH.

## References

1 Hebl JR, Dilger JA, Byer DE, *et al.* A pre-emptive multimodal pathway featuring peripheral nerve block improves perioperative outcomes after major orthopedic surgery. *Reg Anesth Pain Med* 2008; **33**: 510–7

2 Hebl JR, Kopp SL, Ali MH, *et al.* A comprehensive anesthesia protocol that emphasizes peripheral nerve blockade for total knee and total hip arthroplasty. *J Bone Joint Surg Am* 2005; **87** (Suppl. 2): 63–70

3 Ilfeld BM, Le LT, Meyer RS, *et al.* Ambulatory continuous femoral nerve blocks decrease time to discharge readiness after tricompartment total knee arthroplasty: a randomized, triple-masked, placebo-controlled study. *Anesthesiology* 2008; **108**: 703–13

4 Feibel RJ, Dervin GF, Kim PR, Beaule PE. Major complications associated with femoral nerve catheters for knee arthroplasty: a word of caution. *J Arthroplasty* 2009; **24**: 132–7

5 Ilfeld BM, Ball ST, Gearen PF, *et al.* Ambulatory continuous posterior lumbar plexus nerve blocks after hip arthroplasty: a dual-center, randomized, triple-masked, placebo-controlled trial. *Anesthesiology* 2008; **109**: 491–501

6 Ilfeld BM, Duke KB, Donohue MC. The association between lower extremity continuous peripheral nerve blocks and patient falls after knee and hip arthroplasty. *Anesth Analg* 2010; **111**: 1552–4

7 Kandasami M, Kinninmonth AW, Sarungi M, Baines J, Scott NB. Femoral nerve block for total knee replacement—a word of caution. *Knee* 2009; **16**: 98–100

8 Klein SM, Nielsen KC, Greengrass RA, Warner DS, Martin A, Steele SM. Ambulatory discharge after long-acting peripheral nerve blockade: 2382 blocks with ropivacaine. *Anesth Analg* 2002; **94**: 65–70, table of contents

9 Muraskin SI, Conrad B, Zheng N, Morey TE, Enneking FK. Falls associated with lower-extremity-nerve blocks: a pilot investigation of mechanisms. *Reg Anesth Pain Med* 2007; **32**: 67–72

10 Sharma S, Iorio R, Specht LM, Davies-Lepie S, Healy WL. Complications of femoral nerve block for total knee arthroplasty. *Clin Orthop Relat Res* 2010; **468**: 135–40

11 Williams BA, Kentor ML, Bottegal MT. The incidence of falls at home in patients with perineural femoral catheters: a retrospective summary of a randomized clinical trial. *Anesth Analg* 2007; **104**: 1002

12 Church S, Robinson TN, Angles EM, Tran ZV, Wallace JI. Postoperative falls in the acute hospital setting: characteristics, risk factors, and outcomes in males. *Am J Surg* 2011; **201**: 197–202

13 Centers for Medicare and Medicaid Services. Washington DUS-DoHHS. Hospital acquired conditions (present on admission indicator) (Inpatient prospective payment provision). 2010

14 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009; **151**: 264–9, W64

15 Higgins JP, Altman DG, Gotzsche PC, *et al.* The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *Br Med J* 2011; **343**: d5928

16 Stang A. Critical evaluation of the Newcastle–Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol* 2010; **25**: 603–5

17 Mulrow CD, Oxman AD. *Cochrane Collaboration Handbook*, Issue 3. Chichester: John Wiley & Sons, 2001

18 Cook DJ, Sackett DL, Spitzer WO. Methodologic guidelines for systematic reviews of randomized control trials in health care from the Potsdam Consultation on Meta-Analysis. *J Clin Epidemiol* 1995; **48**: 167–71

19 Hatala R, Keitz S, Wyer P, Guyatt G. Tips for learners of evidence-based medicine: 4. Assessing heterogeneity of primary studies in systematic reviews and whether to combine their results. *Can Med Assoc J* 2005; **172**: 661–5

20 Ilfeld BM, Mariano ER, Girard PJ, *et al.* A multicenter, randomized, triple-masked, placebo-controlled trial of the effect of ambulatory continuous femoral nerve blocks on discharge-readiness following total knee arthroplasty in patients on general orthopaedic wards. *Pain* 2010; **150**: 477–84

21 Ilfeld BM, Mariano ER, Madison SJ, *et al.* Continuous femoral versus posterior lumbar plexus nerve blocks for analgesia after hip arthroplasty: a randomized, controlled study. *Anesth Analg* 2011; **113**: 897–903

22 Ilfeld BM, Moeller LK, Mariano ER, *et al.* Continuous peripheral nerve blocks: is local anesthetic dose the only factor, or do concentration and volume influence infusion effects as well? *Anesthesiology* 2010; **112**: 347–54

23 Williams BA, Kentor ML, Vogt MT, *et al.* Reduction of verbal pain scores after anterior cruciate ligament reconstruction with 2-day continuous femoral nerve block: a randomized clinical trial. *Anesthesiology* 2006; **104**: 315–27

24 Wegener JT, van Ooij B, van Dijk CN, Hollmann MW, Preckel B, Stevens MF. Value of single-injection or continuous sciatic nerve block in addition to a continuous femoral nerve block in patients undergoing total knee arthroplasty: a prospective, randomized, controlled trial. *Reg Anesth Pain Med* 2011; **36**: 481–8

25 McGinn T, Wyer PC, Newman TB, Keitz S, Leipzig R, For GG. Tips for learners of evidence-based medicine: 3. Measures of observer variability (kappa statistic). *Can Med Assoc J* 2004; **171**: 1369–73

26 Barrington MJ, Olive DJ, McCutcheon CA, *et al.* Stimulating catheters for continuous femoral nerve blockade after total knee arthroplasty: a randomized, controlled, double-blinded trial. *Anesth Analg* 2008; **106**: 1316–21, table of contents

27 Good RP, Snedden MH, Schieber FC, Polachek A. Effects of a preoperative femoral nerve block on pain management and rehabilitation after total knee arthroplasty. *Am J Orthop (Belle Mead NJ)* 2007; **36**: 554–7

28 Ozen M, Inan N, Tumer F, Uyar A, Baltaci B. The effect of 3-in-1 femoral nerve block with ropivacaine 0.375% on postoperative morphine consumption in elderly patients after total knee replacement surgery. *Agri* 2006; **18**: 44–50

29 Cameron I, Murray GR, Gillespie L, *et al.* Interventions for preventing falls in older people in residential care facilities and hospitals (Protocol). *Cochrane Database Syst Rev* 2005; 1–10

30 Fischer ID, Krauss MJ, Dunagan WC, *et al.* Patterns and predictors of inpatient falls and fall-related injuries in a large academic hospital. *Infect Control Hosp Epidemiol* 2005; **26**: 822–7

31 Choi PT, Bhandari M, Scott J, Douketis J. Epidural analgesia for pain relief following hip or knee replacement. *Cochrane Database Syst Rev* 2003; CD003071

32 Fowler SJ, Symons J, Sabato S, Myles PS. Epidural analgesia compared with peripheral nerve blockade after major knee surgery: a systematic review and meta-analysis of randomized trials. *Br J Anaesth* 2008; **100**: 154–64

33 Bonnet F, Marret E. Influence of anaesthetic and analgesic techniques on outcome after surgery. *Br J Anaesth* 2005; **95**: 52–8

34 Ackerman DB, Trousdale RT, Bieber P, Henely J, Pagnano MW, Berry DJ. Postoperative patient falls on an orthopedic inpatient unit. *J Arthroplasty* 2010; **25**: 10–4

35 Kerzman H, Chetrit A, Brin L, Toren O. Characteristics of falls in hospitalized patients. *J Adv Nurs* 2004; **47**: 223–9

36 Swinkels A, Newman JH, Allain TJ. A prospective observational study of falling before and after knee replacement surgery. *Age Ageing* 2009; **38**: 175–81

37 YaDeau JT, Cahill JB, Zawadsky MW, *et al.* The effects of femoral nerve blockade in conjunction with epidural analgesia after total knee arthroplasty. *Anesth Analg* 2005; **101**: 891–5, table of contents

38 Levinger P, Menz HB, Wee E, Feller JA, Bartlett JR, Bergman NR. Physiological risk factors for falls in people with knee osteoarthritis before and early after knee replacement surgery. *Knee Surg Sports Traumatol Arthrosc* 2011; **19**: 1082–9

39 Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *Br Med J* 2003; **327**: 557–60

# Appendix: Search strategy

Ovid MEDLINE(R) 1946 to January Week 1, 2012

| Step # | Search type | # Searches results |
|---|---|---|
| 1 | Arthroplasty, replacement, knee/or arthroplasty/or arthroplasty, replacement, hip/ | 27 453 |
| 2 | Hip prosthesis/or knee prosthesis/or 1 | 43 666 |
| 3 | Anesthesia, conduction/or exp nerve block/or denervation/ | 32 272 |
| 4 | 2 and 3 | 375 |
| 5 | Muscle weakness/or muscle hypotonia/ | 6751 |
| 6 | Accidental falls/or falls.mp | 28 805 |
| 7 | 4 and (5 or 6) | 7 |
| 8 | 4 and postoperative complications/ | 43 |
| 9 | 7 or 8 | 47 |
| 10 | Limit 9 to humans | 47 |

EBSCO CINAHL 1984 to 2012

| | | |
|---|---|---|
| 1 | (MH 'Nerve Block') or (MH 'Denervation+') | 3040 |
| 2 | (MH 'Arthroplasty, Replacement, Hip') or (MH 'Arthroplasty, Replacement, Knee+') or (MH 'Arthroplasty, Replacement+') or (MH 'Arthroplasty+') | 9608 |
| 3 | S1 and S2 | 101 |
| 4 | (MH 'Accidental Falls') or [MH 'Fall Prevention (Iowa NIC)'] or (MH 'Fall Risk Assessment Tool') or (MH 'Hendrich Fall Risk Model') or (MH 'Morse Fall Scale') or [MH 'Safety Behavior: Fall Prevention (Iowa NOC)'] or [MH 'Safety Status: Falls Occurrence (Iowa NOC)'] | 8672 |
| 5 | S3 and S4 | 2 |

Thompson Reuters Web of Science
Topic=[(hip or knee) and 'nerve block*' and (fall* or postoperative* or walk* or weak*)]
Refined by: Topic=(fall* OR weakness*) Cited references/related references=30

Ovid EMBASE 1988 to 2012 Week 2

| Step # | Search type | # Searches results |
|---|---|---|
| 1 | Arthroplasty, replacement, knee/or arthroplasty/or arthroplasty, replacement, hip/ | 23 891 |
| 2 | Hip prosthesis/or knee prosthesis/or 1 | 31 246 |
| 3 | Anesthesia, conduction/or exp nerve block/or denervation/ | 29 983 |
| 4 | 2 and 3 | 331 |
| 5 | Muscle weakness/or muscle hypotonia/ advanced | 28 771 |
| 6 | Accidental falls/or falls.mp | 34 991 |
| 7 | 4 and (5 or 6) | 6 |
| 8 | 4 and postoperative complications/ | 36 |
| 9 | 7 or 8 | 40 |
| 10 | Limit 9 to humans | 37 |
| 11 | 14 and (prognosis/or risk factors/or treatment outcome/) | 55 |
| 12 | 10 or 11 | 78 |
| 13 | Limit 12 to human | 74 |
| 14 | 13 not case report/ | 64 |

Ovid MEDLINE(R) In-Process and Other Non-Indexed Citations and Ovid MEDLINE® 1946 to Present

| Step # | Search type | # Searches results |
|---|---|---|
| 1 | Exp arthroplasty, replacement, hip/or exp arthroplasty, replacement, knee/ | 21 552 |
| 2 | Hip prosthesis/or knee prosthesis/or exp knee injuries/su or exp hip injuries/su or exp hip joint/su or exp knee joint/ | 70 903 |
| 3 | Anesthesia, conduction/or exp nerve block/or denervation/ | 32 318 |
| 4 | *Femoral nerve/or femoral nerve/in | 1306 |
| 5 | Catheters, indwelling/ae or infusion pumps/ae or 3 | 38 252 |
| 6 | 4 and 5 | 344 |
| 7 | 5 and (1 or 2 or 4) | 790 |
| 8 | 6 or 7 | 790 |
| 9 | Muscle weakness/or muscle hypotonia/or accidental falls/or fall*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier] | 168 780 |

*Continued*

*Continued*

| Step # | Search type | # Searches results |
|---|---|---|
| 10 | 9 and 8 | 14 |
| 11 | (1 or 2 or 4) and pain, postoperative/pc | 504 |
| 12 | 11 and fall*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier] | 3 |
| 13 | 10 or 12 | 14 |
| 14 | 18 or 11 | 1162 |
| 15 | Limit 14 to (clinical trial, all or clinical trial, phase I or clinical trial, phase II or clinical trial, phase III or clinical trial, phase IV or clinical trial or comparative study or controlled clinical trial or evaluation studies or meta-analysis or multicentre study or randomized controlled trial) | 585 |
| 16 | 15 and (postoperative complications/or fall*.mp.) [mp=title, abstract, original title, name of substance word, subject heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier] | 30 |
| 17 | 13 or 16 43 | 43 |
| 18 | 15 and exp clinical trial as topic/18 | 18 |

Ovid EMBASE 1988 to 2012 Week 3

| Step # | Search type | # Searches results |
|---|---|---|
| 1 | Exp knee surgery/or exp hip surgery/ | 51 426 |
| 2 | Nerve block/ | 14 000 |
| 3 | Catheter complication/or femoral nerve catheter/or femoral perineural catheter/ or indwelling catheter/ | 8027 |
| 4 | Postoperative pain/or postoperative analgesia/ | 35 048 |
| 5 | 1 and (2 or 3 or 4) and fall*.mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] | 33 |

The first search strategy was executed in the Ovid MEDLINE database, and the retrieval reviewed for articles identified as benchmarks. Several key articles were not included in the original strategy. The second iteration of the strategy included delivery methods, such as catheters and infusion pumps and also muscle weakness. Then the search strategy was modified to the controlled vocabularies used in EMBASE, and CINAHL. The Web of Science database used only text-words. All of the studies retrieved were entered in the bibliographic database manager EndNote, and duplicate citations removed from the total of 164.

*Handling editor: R. P. Mahajan*

ventilatory response by low dose halothane in humans. *Anesthesiology* 2004; **101**: 1409–16
8 Pandit JJ. The variable effect of low dose volatile anaesthetics on the acute ventilatory response to hypoxia in humans: a quantitative review. *Anaesthesia* 2002; **57**: 632–43
9 Pandit JJ, Manning-Fox J, Dorrington KL, Robbins PA. Effects of subanaesthetic sevoflurane on ventilation. 2. The response to acute and sustained hypoxia in humans. *Br J Anaesth* 1999; **83**: 210–6
10 Pandit JJ, Buckler KJ. Differential effects of halothane and sevoflurane on hypoxia-induced intracellular calcium transients of neonatal rat carotid body type I cells. *B J Anaesth* 2009; **103**: 701–10
11 Pandit JJ, Winter V, Bayliss R, Buckler KJ. Differential effects of halothane and isoflurane on carotid body glomus cell intracellular $Ca^{2+}$ and background $K^+$ channel responses to hypoxia. *Adv Exp Med Biol* 2010; **669**: 205–8
12 Lynch C. Differential depression of myocardial contractility by halothane and isoflurane in vitro. *Anesthesiology* 1986; **64**: 620–31
13 Irifune M, Sato T, Kamata Y, Nishikawa T, Dohi T, Kawahara M. Evidence for GABA(A) receptor agonistic properties of ketamine: convulsive and anesthetic behavioral models in mice. *Anesth Analg* 2000; **91**: 1542–9
14 Hapfelmeier G, Zieglgänsberger W, Haseneder R, Schneck H, Kochs E. Nitrous oxide and xenon increase the efficacy of GABA at recombinant mammalian GABA(A) receptors. *Anesth Analg* 2000; **91**: 1542–9

doi:10.1093/bja/aet562

## Do continuous 'lumbar plexus' blocks really increase the risk of falls?

Editor—I read with interest the recent review published by Johnson and colleagues[1] on falls after major orthopaedic surgery. The authors should be congratulated for demonstrating that the frequency of falls in orthopaedic patients benefiting from continuous 'lumbar plexus blocks' was similar to the frequency of falls observed in surgical patients. This conclusion was based on an analysis of more than 4000 patients. Their data confirm our previously published findings from a data analysis of falls from our own hospital.[2] Even though the authors were extremely careful in the choices they made, and discussed a number of limitations for their analysis, they failed to acknowledge several selection biases.

It is surprising that the study by Williams and colleagues[3] was included as a randomized trial when the report on falls from this study was published later as a letter to the editor[4] and not reported as an endpoint in the method section of the original paper.[3] This contrasts with the obvious assumption that if a study was published, even if the stated goal was to assess complications, if falls was not a key word, it meant that falls was not included as an endpoint rather than a non-event.[2]

The frequency of falls has been reported to be directly related to a number of pre-, peri-, and postoperative factors including preoperative history of falls,[5] advanced age,[2] and mobilization without supervision.[2] Since none of the studies included in this analysis was controlled for these factors how is it possible to conclude that the difference among the groups was related to the presence or absence of blocks and not due to a difference in the patient distribution in terms of preoperative history of falls, the number of elderly and very elderly patients, or the number of patients who walked without supervision?[3]

A fall is an established complication of joint replacement. In these conditions, it is surprising that Johnson and colleagues[1] included cohort studies related to blocks in their analysis but did not include studies not involving blocks. This would certainly provide a more balanced evaluation.[4] It is also surprising that the authors did not include the Ackerman and colleagues' study[6] as one of their cohort studies, since the study included 6912 patients with and without blocks.

In conclusion, there is no doubt that a large randomized prospective study focusing on falls would greatly help in determining the role that nerve blocks may play in falls after joint replacement. However, in the current trend including the use of low concentration, low volume of local anaesthetics, it is uncertain that 'lumbar plexus' blocks really affect quadriceps function in patients undergoing total knee replacement, since it is established that the surgery itself reduces quadriceps function by 60%.[7]

## Declaration of interest

None declared.

J. E. Chelly
*Pittsburgh, USA*
*E-mail: chelje@anes.upmc.edu*

1 Johnson RL, Kopp SL, Hebl JR, Erwin PJ, Mantilla CB. Falls and major orthopaedic surgery with peripheral nerve blockade: a systematic review and meta-analysis. *Br J Anaesth* 2013; **110**: 518–28
2 Chelly JE, Miller G, Conroy L, Hudson M, Williams JP. Falls in hospitalized patients in a Community Hospital: an endemic problem. *J Patient Safety* 2008; **4**: 178–83
3 Williams BA, Kentor ML, Bottegal MT. The incidence of falls at home in patients with perineural femoral catheters: a retrospective summary of a randomized clinical trial. *Anesth Analg* 2007; **104**: 1002
4 Williams BA, Kentor ML, Vogt MT, *et al.* Reduction of verbal pain scores after anterior cruciate ligament reconstruction with two-day continuous femoral nerve block: a randomized clinical trial. *Anesthesiology* 2006; **104**: 315–27
5 Swinkels A, Newman JH, Allain TJ. A prospective observational study of falling before and after knee replacement surgery. *Age Ageing* 2009; **38**: 175–81
6 Ackerman DB, Trousdale RT, Bieber P, Henely J, Pagnano MW, Berry DJ. Postoperative patient falls on an orthopedic inpatient unit. *J Arthroplasty* 2010; **25**: 10–4
7 Stevens JE, Mizner RL, Snyder Mackler L. Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis. *J Orthop Res* 2003; **21**: 775–9

doi:10.1093/bja/aet563

## Use of the i-gel in unexpected difficult airway

Editor—We support the findings as reported by Theiler and colleagues.[1] In our study, we reported comparable results.