Original Article

Efficacy of Ultrasound-Guided Caudal Epidural Block for Postoperative Analgesia in Patients Undergoing Femur Fracture Surgery under Subarachnoid Block

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Abstract

Background: Femur fracture surgery is commonly associated with significant postoperative pain, which may delay mobilisation and recovery. Although subarachnoid block provides effective intraoperative anaesthesia, its postoperative analgesic duration is limited. Ultrasound-guided caudal epidural block may provide extended analgesia and reduce systemic analgesic requirement. **Material and Methods:** This hospital-based, prospective, randomized controlled study included 70 patients undergoing femur fracture surgery under subarachnoid block. Patients were randomly allocated into two groups of 35 each. Group A received ultrasound-guided caudal epidural block with 0.2% ropivacaine at 0.3 ml/kg, while Group B received conventional intravenous analgesia. Postoperative pain was assessed using the Visual Analogue Scale at 2-hour intervals for 24 hours. Time to first rescue analgesia, total tramadol consumption, and complications were recorded. **Results:** Baseline demographic and operative characteristics were comparable between groups. VAS scores were consistently lower in the caudal block group throughout the 24-hour postoperative period. Time to first rescue analgesia was longer and total tramadol consumption was lower in Group A, although differences were not statistically significant. Complications were comparable between groups. **Conclusion:** Ultrasound-guided caudal epidural block is a safe and feasible adjunct for postoperative analgesia after femur fracture surgery, with a favourable trend toward better pain control and reduced opioid requirement.

Keywords: caudal epidural block, femur fracture, postoperative analgesia, ropivacaine, subarachnoid block, ultrasound guidance.

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Introduction

Femoral fractures frequently require operative fixation and can produce substantial postoperative pain from periosteal injury, tissue dissection, inflammation, and surgical manipulation. Inadequate analgesia can hinder mobilisation and physiotherapy, intensify the stress response, and contribute to pulmonary complications, venous thromboembolism, delirium, and longer hospitalisation. Morrison et al. reported that greater pain after hip-fracture surgery was associated with delayed walking and poorer clinical outcomes.[1]

Subarachnoid block is widely used for lower-limb orthopaedic operations because it acts rapidly, provides reliable sensory and motor anaesthesia, and avoids routine airway instrumentation. Its analgesic benefit diminishes as the spinal drug wears off, leaving a need for effective postoperative pain control.

Analgesic planning is therefore most important during the first postoperative day, when nursing activity and mobilisation often begin. Severe early pain may also promote central sensitisation and persistent pain. Kehlet et al. identified poorly controlled acute pain as an important contributor to chronic postsurgical pain, underscoring the value of timely perioperative analgesia.[2]

Systemic opioids, non-steroidal anti-inflammatory drugs, and paracetamol are common after femur-fracture surgery, but each has limitations. Opioids can cause nausea, vomiting, sedation, respiratory depression, urinary retention, ileus, pruritus, and delirium. Non-steroidal drugs may be unsuitable in renal impairment, gastrointestinal disease, platelet dysfunction, or situations where bone healing is a concern. Combining agents and regional techniques can improve analgesia while limiting exposure to any single drug; this is the principle of multimodal analgesia described by Buvanendran and Kroin.[3]

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Regional techniques are increasingly incorporated into orthopaedic pain pathways. In adults with hip fracture, a Cochrane review found that peripheral nerve blocks reduced movement-related pain and acute confusion.[4] Observational perioperative data also associate regional anaesthesia with lower systemic analgesic exposure and improved recovery profiles.[5] Caudal epidural block introduces local anaesthetic through the sacral hiatus to reach sacral and lower lumbar roots. Although used most often in children, ultrasound has renewed interest in its application to adults.

In adults, anatomical variation in the sacral hiatus can make a landmark-only caudal approach unreliable and may increase the risk of failed, vascular, or intrathecal placement. Sonography permits direct identification of the cornua, hiatus, sacrococcygeal ligament, needle path, and injectate spread. Chen et al. documented improved caudal needle placement with ultrasound.[6] and Vadhanan et al. demonstrated that the technique is feasible in adult surgical practice.[7]

Ropivacaine was selected because it is a long-acting amide local anaesthetic that can provide sensory analgesia with less motor block and lower cardiotoxic potential than bupivacaine. Its reduced lipophilicity limits penetration of large myelinated motor fibres, an attribute that may assist early mobilization.[8]

Adult orthopaedic studies suggest that caudal epidural analgesia can reduce pain, postpone rescue medication, and decrease supplementary analgesic use. Nishio et al. compared caudal epidural block with continuous femoral block and intravenous patient-controlled analgesia after total hip arthroplasty and reported effective pain relief with regional approaches.[9] Dose-finding work has further supported the feasibility of ultrasound-guided caudal ropivacaine in adults.[10] Evidence specific to femur-fracture surgery performed under subarachnoid block, however, remains limited.

The study therefore compared ultrasound-guided caudal epidural block with conventional intravenous analgesia in adults undergoing femur-fracture surgery under subarachnoid block. Prespecified outcomes were serial VAS scores during the first 24 hours, time to first rescue analgesia, and total 24-hour analgesic requirement.

Materials and Methods

This prospective randomised controlled study was conducted in the Department of Anaesthesiology at Mahatma Gandhi Medical College and Hospital, Jaipur, from April 2024 through September 2025. Institutional Ethics Committee approval and written informed consent were obtained. Seventy patients were assigned in equal numbers by a computer-generated randomisation schedule. Eligible participants were 18–65 years old, of either sex, classified as American Society of Anesthesiologists physical status I–III, and scheduled for femur-fracture surgery under subarachnoid block. Demographic, clinical, and investigation data were recorded on a predesigned form. Exclusion criteria were refusal to participate, a bleeding disorder, anticoagulant treatment, neurological deficit, relevant drug allergy, infection at the injection site, or current sedative or antipsychotic medication. Group A received ultrasound-guided caudal epidural 0.2% ropivacaine at 0.3 mL/kg. Group B received the institution's conventional intravenous analgesic regimen and served as the control arm.

All participants received intravenous ondansetron 4 mg before anaesthesia. Fasting requirements were confirmed, intravenous access was established, and electrocardiography, heart rate, non-invasive arterial pressure, oxygen saturation, temperature, respiratory gases, and capnography were monitored. Supplemental oxygen was delivered by face mask. With the patient sitting or in the lateral position, a 25-gauge needle was introduced at L3–L4. After free cerebrospinal fluid return, 3 mL of 0.5% hyperbaric bupivacaine (15 mg) was injected intrathecally. Surgery began after confirming an appropriate sensory level not above T8.

After surgery, Group A patients were positioned laterally with the operated side uppermost. The sacral cornua, hiatus, and sacrococcygeal ligament were first identified in the transverse sonographic view; the probe was then rotated into the longitudinal plane. A 22-gauge spinal needle was advanced in-plane at approximately 45° until penetration of the sacrococcygeal ligament was seen. Following negative aspiration for blood and cerebrospinal fluid, the calculated ropivacaine volume was injected and spread within the caudal epidural space was confirmed by ultrasound.

VAS was recorded at 0 hours and every 2 hours thereafter through 24 hours. Rescue analgesia was administered when VAS exceeded 4, using intravenous tramadol 2 mg/kg within a maximum daily exposure of 5 mg/kg. Time to first rescue dose, cumulative 24-hour tramadol consumption, haemodynamic measurements, and recorded complications were documented; haemodynamic observations continued at 2-hour intervals for 24 hours.

Patient-level data were entered in Microsoft Excel and analysed using two-sided tests. Categorical variables are reported as number and percentage [N (%)], and continuous variables as mean with standard deviation [mean (SD)]. Distributional form was checked with the Shapiro–Wilk test and graphical inspection. Continuous outcomes were compared with Welch's independent-samples t-test. Pearson's chi-square test was used for categorical tables with adequate expected counts; Fisher's exact test was used for sparse 2 × 2 tables, and the Fisher–Freeman–Halton exact test was used for sparse multi-category tables. Statistical significance was defined as $p<0.05$. The time-specific VAS p-values are unadjusted; a Holm correction was additionally examined to assess multiplicity.

Results

All 70 randomised participants contributed complete outcome data, with 35 patients in each arm. Group A received ultrasound-guided caudal epidural 0.2% ropivacaine and Group B received conventional intravenous analgesia. The analysis covered baseline and operative variables, serial VAS measurements, rescue-analgesia timing, cumulative 24-hour tramadol exposure, and postoperative adverse events.

Baseline demographic profile: The randomised groups were

similar at enrolment. Mean age was 45.1 ± 10.4 years in Group A and 45.9 ± 12.4 years in Group B (t = −0.302, p = 0.763). Mean weight was 65.7 ± 8.4 kg and 65.2 ± 9.0 kg, respectively (t = 0.236, p = 0.814), while mean body mass index was 24.94
± 2.86 kg/m² in Group A and 25.05 ± 2.88 kg/m² in Group B (t = −0.158, p = 0.875).
Sex distribution did not differ between groups: Group A included 20 males (57.1%) and 15 females (42.9%), and Group B included 21 males (60.0%) and 14 females (40.0%) (χ^2 = 0.059, p = 0.808). The comorbidity profile was also balanced on the Fisher–Freeman–Halton exact test (p = 0.180).
[Table 1] summarises the demographic and comorbidity comparisons. No baseline variable showed evidence of an important between-group imbalance.

Table 1: Baseline demographic and comorbidity characteristics

Variable	Group A	Group B	Test statistic	p-value
Age, years	45.1 (10.4)	45.9 (12.4)	t = −0.302	0.763
Male	20 (57.1%)	21 (60.0%)	χ^2 = 0.059	0.808
Female	15 (42.9%)	14 (40.0%)	—	—
Weight, kg	65.7 (8.4)	65.2 (9.0)	t = 0.236	0.814
BMI, kg/m²	24.94 (2.86)	25.05 (2.88)	t = −0.158	0.875
No comorbidity	20 (57.1%)	13 (37.1%)	Pobs = 0.001571	0.180
Hypertension	7 (20.0%)	8 (22.9%)	—	—
Diabetes mellitus	4 (11.4%)	11 (31.4%)	—	—
Hypertension + diabetes	4 (11.4%)	3 (8.6%)	—	—

Values are mean (SD) or N (%). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. Welch's independent-samples t-test was used for continuous variables, Pearson's chi-square test for sex, and the Fisher–Freeman–Halton exact test for comorbidities. Pobs is the conditional probability of the observed sparse table. Overall categorical test results appear on the first category row.
Significance was set at p<0.05; * denotes significance. BMI: body mass index; kg: kilograms; m: metres; N: number; SD: standard deviation.

Clinical and operative profile: ASA physical status was comparable between groups (χ^2 = 1.552, p = 0.460). Group A included 8 patients (22.9%) with ASA I, 18 (51.4%) with ASA II, and 9 (25.7%) with ASA III; the corresponding Group B counts were 5 (14.3%), 23 (65.7%), and 7 (20.0%).
Fracture location was identical across groups: each arm contained 14 intertrochanteric fractures (40.0%), 12 shaft fractures (34.3%), and 9 distal femur fractures (25.7%) (χ^2 = 0.000, p = 1.000). Right-sided surgery occurred in 19 patients (54.3%) in Group A and 15 (42.9%) in Group B (χ^2 = 0.915, p = 0.339).
Mean operating time was 106.2 ± 13.4 minutes in Group A and 111.4 ± 17.7 minutes in Group B (t = −1.384, p = 0.171). ASA grade, fracture location, operated side, and procedure distribution were likewise comparable. These clinical and operative data are reported in [Table 2 and 3].

Table 2: Clinical and operative profile

Variable	Group A	Group B	Test statistic	p-value
ASA I	8 (22.9%)	5 (14.3%)	χ^2 = 1.552	0.460
ASA II	18 (51.4%)	23 (65.7%)	—	—
ASA III	9 (25.7%)	7 (20.0%)	—	—
IT fracture	14 (40.0%)	14 (40.0%)	χ^2 = 0.000	1.000
Shaft fracture	12 (34.3%)	12 (34.3%)	—	—
Distal fracture	9 (25.7%)	9 (25.7%)	—	—
Right side	19 (54.3%)	15 (42.9%)	χ^2 = 0.915	0.339
Left side	16 (45.7%)	20 (57.1%)	—	—
Surgery duration, min	106.2 (13.4)	111.4 (17.7)	t = −1.384	0.171

Values are mean (SD) or N (%). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. Welch's independent-samples t-test was used for surgery duration and Pearson's chi-square test for categorical variables. Overall categorical results appear on the first category row. Significance was set at p<0.05; * denotes significance. ASA: American Society of Anesthesiologists; IT: intertrochanteric; min: minutes; N: number; SD: standard deviation.

Table 3: Type of surgical procedure

Procedure	Group A	Group B	Test statistic	p-value
PFN	12 (34.3%)	14 (40.0%)	Pobs = 0.000652	0.636
DHS	2 (5.7%)	0 (0.0%)	—	—
IMIL nailing	8 (22.9%)	6 (17.1%)	—	—
Shaft femur plating	4 (11.4%)	6 (17.1%)	—	—
Distal femur plating	6 (17.1%)	8 (22.9%)	—	—
Retrograde nailing	3 (8.6%)	1 (2.9%)	—	—

Values are N (%). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. The Fisher–Freeman–Halton exact test was used because expected counts were sparse. Pobs is the conditional probability of the observed table; the overall test result appears on the first row. Significance was set at $p<0.05$; * denotes significance. DHS: dynamic hip screw; IMIL: interlocking intramedullary; N: number; PFN: proximal femoral nail.

Postoperative pain scores: Immediate postoperative VAS scores were nearly identical (0.96 ± 0.49 in Group A versus 0.95
± 0.44 in Group B; $p = 0.918$). From 2 hours onward, mean VAS was consistently lower in Group A. Unadjusted Welch tests were significant at 2, 4, 6, 8, 10, 12, 14, 18, 22, and 24 hours, but not at 16 or 20 hours. Following Holm correction across the 13 assessments, the differences at 2–14, 22, and 24 hours remained significant, whereas the 18-hour comparison did not.

The separation was most pronounced during the early and middle postoperative period. At 8 hours, mean VAS was 2.62 ± 0.40 in Group A and 4.55 ± 0.57 in Group B, corresponding to a mean difference of −1.93 points (95% CI −2.17 to −1.70; $p<0.001$).

Group A reached its highest mean VAS at 14–16 hours (3.54), whereas Group B peaked at 10 hours (4.56). Scores then declined in both groups, although a significant difference remained at 22 and 24 hours. The complete trajectory with 95% confidence intervals, and time-specific estimates, test statistics, and p-values are provided in [Table 4].

Table 4: Postoperative Visual Analogue Scale scores over 24 hours

Time after surgery	Group A VAS	Group B VAS	Test statistic	p-value
0 h	0.96 (0.49)	0.95 (0.44)	t = 0.103	0.918
2 h	1.31 (0.53)	1.75 (0.45)	t = −3.802	<0.001*
4 h	1.69 (0.41)	3.00 (0.44)	t = −12.970	<0.001*
6 h	2.20 (0.32)	3.93 (0.48)	t = −17.720	<0.001*
8 h	2.62 (0.40)	4.55 (0.57)	t = −16.509	<0.001*
10 h	2.92 (0.45)	4.56 (0.49)	t = −14.528	<0.001*
12 h	3.25 (0.47)	4.26 (0.46)	t = −9.027	<0.001*
14 h	3.53 (0.44)	4.02 (0.53)	t = −4.174	<0.001*
16 h	3.54 (0.38)	3.73 (0.46)	t = −1.856	0.068
18 h	3.44 (0.42)	3.66 (0.42)	t = −2.228	0.029*
20 h	3.34 (0.42)	3.53 (0.54)	t = −1.634	0.107
22 h	3.12 (0.36)	3.45 (0.46)	t = −3.388	0.001*
24 h	2.93 (0.49)	3.30 (0.46)	t = −3.235	0.002*

Values are mean (SD). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. Welch's independent-samples t-test was used at each
time point. The displayed p-values are unadjusted; after Holm correction, differences remained significant at 2–14, 22, and 24 h. Significance was set at $p<0.05$; * denotes an unadjusted significant p-value. h: hours; SD: standard deviation; VAS: Visual Analogue Scale.

Time to first rescue analgesia: Time to first rescue analgesia was longer after caudal block: 13.05 ± 1.88 hours in Group A versus 7.77 ± 1.48 hours in Group B. The mean extension of the rescue-free interval was 5.27 hours (95% CI 4.46–6.08; t = 13.038, $p<0.001$), as shown in [Table 5].

Table 5: Rescue analgesia and total tramadol consumption

Outcome	Group A	Group B	Test statistic	p-value
Time to first rescue, h	13.05 (1.88)	7.77 (1.48)	t = 13.038	<0.001*
Tramadol in 24 h, mg	145.0 (30.8)	282.9 (40.6)	t = −16.012	<0.001*

Values are mean (SD). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. Welch's independent-samples t-test was used. Significance was set at $p<0.05$; * denotes significance. h: hours; mg: milligrams; SD: standard deviation.

Total tramadol consumption in the first 24 hours: Twenty-four-hour tramadol use was 145.0 ± 30.8 mg in Group A and 282.9 ± 40.6 mg in Group
B. This represented a mean reduction of 137.86 mg with caudal block (95% CI 120.65–155.06 mg; t = −16.012, $p<0.001$). The participant-level distribution is shown and corresponding summary statistics are provided in Table 5.

Postoperative complications: Nausea or vomiting occurred in 4 patients (11.4%) in Group A and 16 patients (45.7%) in Group B (odds ratio = 0.153, Fisher's exact p = 0.003). This difference coincided with the substantially lower tramadol exposure in Group A. All adverse-event comparisons are presented in [Table 6].

Table 6: Postoperative complications

Complication	Group A	Group B	Test statistic	p-value
Nausea and vomiting	4 (11.4%)	16 (45.7%)	OR = 0.153	0.003*
Hypotension	6 (17.1%)	7 (20.0%)	OR = 0.828	1.000
Bradycardia	3 (8.6%)	4 (11.4%)	OR = 0.727	1.000
Other complication	0 (0.0%)	2 (5.7%)	OR = 0.000	0.493

Values are N (%). Group A: ultrasound-guided caudal epidural block; Group B: conventional intravenous analgesia. Two-sided Fisher's exact test was used, and the odds ratio is reported as the test statistic. Significance was set at $p<0.05$; * denotes significance.

N: number; OR: odds ratio.

Hypotension affected 6 patients (17.1%) in Group A and 7 (20.0%) in Group B ($p = 1.000$), while bradycardia occurred in 3 (8.6%) and 4 (11.4%), respectively ($p = 1.000$). No other complication was recorded in Group A; two patients (5.7%) in Group B had another event ($p = 0.493$). These data do not indicate excess adverse events attributable to the ultrasound-guided block, although the sample was not large enough to exclude uncommon complications.

Discussion

This randomised study found a clear postoperative analgesic advantage for ultrasound-guided caudal epidural ropivacaine. VAS scores separated by 2 hours and remained lower through most of the 24-hour observation period. The block also extended the mean rescue-free interval by 5.27 hours and reduced tramadol exposure by approximately 138 mg. These outcomes matter after femur fracture surgery because poorly controlled pain can impede mobilisation and rehabilitation. Morrison et al. linked greater pain after hip fracture surgery with delayed ambulation and poorer outcomes.[1] while Kehlet et al. described severe acute pain as a contributor to persistent postsurgical pain.[2]

Pain increased in both groups as the spinal anaesthetic receded, but the rise was smaller among patients who received caudal ropivacaine. This temporal pattern supports an added postoperative effect from the caudal injection. It also illustrates the multimodal principle: regional and systemic approaches can act through different mechanisms to improve pain control while limiting drug-related toxicity, as discussed by Buvanendran and Kroin.[3] and by Kehlet and Dahl.[11]

The sustained VAS reduction is compatible with the broader evidence for regional analgesia in orthopaedic care. Guay and Kopp found that peripheral nerve blocks reduce pain on movement in adults with hip fracture.[4] In a large orthopaedic cohort, Memtsoudis et al. associated regional techniques with improved perioperative outcomes.[5] Liu and Wu likewise concluded that analgesic technique can influence recovery through pain control and reduced opioid exposure.[12] Although these sources evaluate different blocks and populations, they provide a coherent clinical context for the present result.

The 5.27-hour increase in time to first rescue medication indicates prolonged analgesic coverage rather than a small directional trend. Ropivacaine is a plausible contributor because it provides long-acting sensory blockade with less motor block than bupivacaine, as reviewed by Kuthiala and Chaudhary.[8] Volunteer data from Knudsen et al. also support its comparatively favourable systemic safety profile.[13]

The reduction of approximately 138 mg in 24-hour tramadol requirement represents a substantial opioid-sparing effect. The parallel fall in nausea or vomiting is biologically plausible, although the study was not designed to establish mediation by tramadol exposure.

Reduced opioid use is clinically relevant because it may limit sedation, dizziness, gastrointestinal symptoms, and delay in mobilisation.

Recorded haemodynamic complications were similar between groups, and no additional complication occurred in the caudal-block arm. These findings are reassuring but cannot establish safety for rare events. Ultrasound may improve procedural control by identifying the sacral cornua, hiatus, sacrococcygeal ligament, and needle path. Chen et al. reported improved caudal needle placement with ultrasound.[6] Vadhanan et al. described its feasibility in adults.[7] and Klocke et al. demonstrated sonographic localisation of the sacral hiatus.[14]

The direction of benefit is consistent with Nishio et al., who compared several postoperative analgesic strategies after total hip arthroplasty and found better early pain control with regional techniques than with systemic analgesia alone.[9] In the present dataset, the largest VAS separation occurred between 4 and 12 hours, when spinal anaesthesia would be expected to regress. The immediate postoperative scores were similar, supporting baseline comparability rather than an artifactual group difference at time zero.

Dose and adjuvant selection may still influence the duration and magnitude of benefit. Bhardwaj et al. reported prolonged analgesia when morphine was added to local anaesthetic for ultrasound-guided caudal block.[15] Ma et al. showed that ropivacaine concentration and volume affect block success.[10] The present protocol used 0.2% ropivacaine at 0.3 mL/kg; future trials could compare this regimen with alternative volumes or carefully selected adjuvants while monitoring motor block and systemic toxicity.

Evidence from other settings is supportive but indirect. Bozkurt et al. reported longer postoperative analgesia with caudal epidural than with spinal anaesthesia in adults having ambulatory perianal surgery.[16] In paediatric hip and proximal-femur surgery, Elshazly et al. found caudal analgesia comparable with an erector spinae plane block.[17] Differences in age, operation, and comparator mean that these studies should be used for context rather than direct equivalence with the present population.

Repeated pain measurements require attention to multiplicity. The unadjusted 18-hour p-value was significant, but it did not remain so after Holm correction; the differences at 2–14, 22, and 24 hours did remain significant. This pattern, together with the large and precisely estimated differences in rescue time and tramadol consumption, is more informative than any single time-

point p-value. Altman and Bland cautioned against equating a non-significant result with proof of no effect.[18] Clinically, the block should be viewed as one component of multimodal recovery rather than a stand-alone solution, consistent with the approach discussed by White and Kehlet.[19]

Limitations: This was a single-centre study with 35 participants per group, so uncommon adverse events and subgroup effects could not be estimated reliably. Pain ratings are subjective, and blinding of participants and assessors was not documented. Multiple VAS comparisons were performed; therefore, both

unadjusted results and Holm-adjusted interpretation are reported. The study did not assess mobilisation, length of stay, patient satisfaction, persistent pain, or longer-term functional recovery. These limitations restrict generalisability beyond similar femur-fracture populations and perioperative protocols.

Conclusion

In this 70-patient study, ultrasound-guided caudal epidural ropivacaine improved postoperative analgesia after femur fracture surgery under subarachnoid block. It lowered VAS scores over most of the first 24 hours, prolonged time to rescue medication, and substantially reduced tramadol use. Nausea or vomiting was less frequent, and no significant increase was detected in hypotension, bradycardia, or other recorded complications. These findings support the technique as an effective multimodal analgesic adjunct while recognizing the limits of a single-centre sample.

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Conflicts of interest

There are no conflicts of interest.

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