Original Article

Anesthesia for Removal of External Fixation with Hydroxyapatite-Coated Half Pins

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Abstract

Background: External fixation utilizing hydroxyapatite (HA)-coated half pins has produced excellent clinical results revolutionizing the field of limb lengthening and deformity correction surgery. Removal of these pins is a painful patient experience that may be best conducted under anesthesia. **Purpose:** The current study documents how a deformity practice removes these external fixators (frames) under anesthesia. We asked: (1) How much anesthesia is needed for frame removal? (2) How effective was this protocol in controlling patient pain? (3) How did patients taking narcotic medications at the time of frame removal differ from those not taking narcotics during frame removal surgery? **Patients and Methods:** We prospectively recorded data during the removal of 53 consecutive external fixators that used HA-coated half pins including the use of pre operative narcotics at the time of frame removal, location and complexity of frames, type and dosages of medications administered, and adequacy of anesthesia. **Results:** All patients were managed with a combination of midazolam, propofol, fentanyl, and ketamine. Anesthesia was graded as good to excellent in 91% and unsatisfactory to poor in 9% of cases. The preoperatively medicated group was administered significantly less fentanyl (P = 0.020) and had significantly more frames located about the ankle and foot (P = 0.049) than the preoperatively non-medicated cohort. **Conclusions:** IV sedation administered by an anesthesiologist in the operating room provided adequate pain control to perform fixator removal and pin site debridement in most cases. External fixation used for foot and ankle reconstruction may provide a more painful experience for patients.

Keywords: *Anesthesia, deformity external fixation, hydroxyapatite-coated pin, ilizarov*

Introduction

External fixation utilizing hydroxyapatite (HA)-coated half pins has produced excellent clinical results revolutionizing the field of limb lengthening and deformity correction surgery.[1-8] Bone lengthening, bone transport, arthrodesis, joint distraction, and fracture fixation have all benefited from gradual adjustability through osseous compression, or distraction.[2-4,7-10] The excellent fixation provided by these pins has emboldened surgeons to push the limits of integrated fixation where internal implants are placed in close proximity to the half pins.[9,11-13] This scenario relies heavily on strong pin fixation as a product that provides low risk for deep infection. Limb lengthening and reconstruction procedures require a minimum of 3 months and up to 18 months or more of fixation. Tapered HA-coated pins bind to the pin-bone interface improving frame stability, decreasing pin discomfort and infection, and resisting loosening.[5,14-16] It has been suggested that the removal of external fixation may be satisfactorily performed in the clinic rather than under anesthesia in the operating room (OR).[17,18] It has been our impression that well-fixed HA-coated half-pins cause more pain to remove than those that have loosened, a finding also observed by others.[19] HA-coated half-pins make a stronger bond to the patient's bone than uncoated pins, requiring a higher extraction torque when they are removed.[15,20] In our experience, it is common to remove a bone transport frame that has been mounted for 1.5 years and find no pin loosening with normal extraction resistance. This is juxtaposed to the common finding among noncoated pins used in trauma (pin-to-bar frames)[21] where on removal 3 months after application, the pins are falling out of the bone. This disparity has been echoed in prospective studies measuring extraction torque.[15,19] Due to the phenomenal binding of the

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HA-coated pins to bone, we remove all external fixators that utilize these pins in the OR under sedation. We have also noted that adhesions develop between the skin and the bone at the pin sites resulting in painful puckering of the skin. It has been our practice to remove fixators in the OR and to perform a thorough debridement of pin sites including a release of subcutaneous adhesions. To the best of our knowledge, no prior study has examined the removal of external fixators utilizing HA-coated pins in the OR.

The purpose of this study was to document how surgeons in a deformity practice remove external fixators with HA-coated pins. We asked the following questions: (1) How much anesthesia is needed for frame removal? (2) How effective was this protocol in controlling patient pain during the removal process? (3) How did patients taking narcotic medications at the time of frame removal differ from those not taking narcotics with respect to surgical details and the anesthetic needs during frame removal surgery?

Methods

Approval for the study was obtained from our Institutional Review Board. We prospectively recorded data on 53 consecutive patients undergoing external fixator removal procedures. Inclusion criteria included any patient operated on with an external fixator who had completed treatment and was indicated for frame removal. No one was excluded from this consecutive series of frame removals.

History of patients with external fixator treatment

All frames were applied for the purposes of limb lengthening and/or complex limb reconstruction using a mix of tensioned wires and HA-coated half pins which has become the standard in the field. In all cases, the pins were 5–6 mm tapered tip, cortical thread, HA-coated Schantz screws from Biomet (Warsaw, IN, USA). At the index surgery, all pin sites were predrilled with a 4.8 mm drill bit, and half pins were inserted by hand to the ideal depth of penetration as proven on intraoperative fluoroscopy. External fixators were mostly circular with Taylor Spatial Frame (Smith and Nephew, Memphis, TN, USA) rings and either struts or threaded connecting rods [Figures 1-3]. Wires were 1.8 mm stainless steel Ilizarov tensioned smooth or beaded (olive) wires. Some external fixators were monolateral rail frames that used all half pins [Figure 4]. Postoperative care included daily pin dressing changes. Pins were cleaned with diluted hydrogen peroxide and sterile cotton swabs and then wrapped with gauze dressings. Most patients were allowed weight bearing as tolerated ambulation. Patients followed up every 2–4 weeks, depending on the indication for surgery, until bony union, or completion of the intended treatment.

Surgical technique

Frame removal was performed in the OR at one institution. No effort was made to specify an anesthetic protocol or limit the number of anesthesiologists who participated in these procedures. All pins were removed from the bones with a special hand-powered, extraction device able to deliver high torque safely.

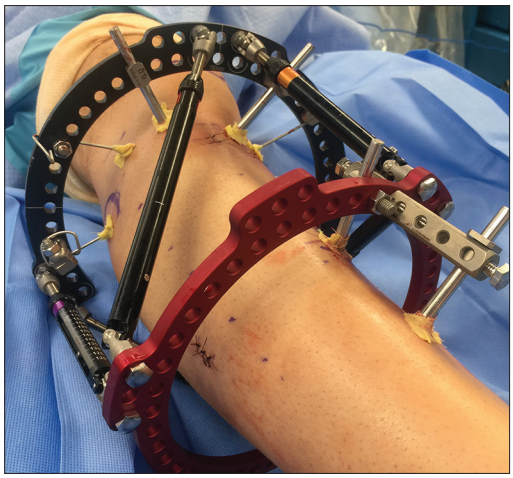

Figure 1: This is a typical circular fixator utilizing hydroxyapatite-coated half pins. The frame location is on the tibia, and the frame size is two rings

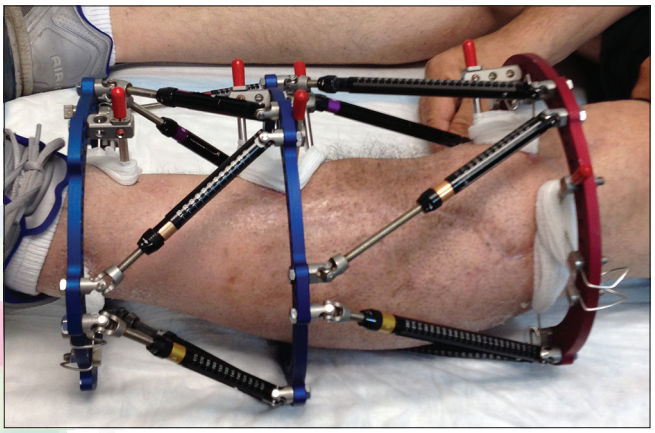

Figure 2: This tibia frame has stacked Taylor spatial frame struts raising the complexity of the case. The frame size is in the 3+ ring category

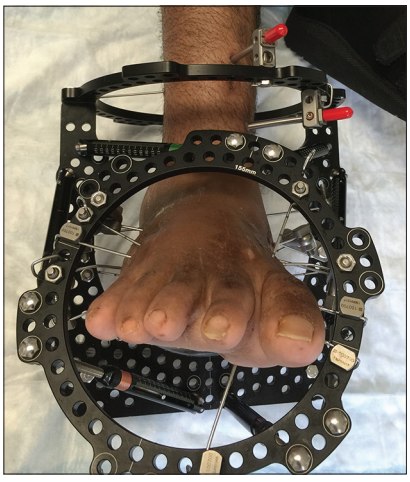

Figure 3: This midfoot deformity correction frame is categorized as a foot frame and is in the 3+ ring group

This tool was created by Orthofix (Lewisville, TX) for the explicit purpose of removing HA-coated pins which previously caused mechanical breakdown of standard hand chuck equipment.[Figure 5a-c]. Once the frames were removed, the extremity was prepped sterilely and the pin sites were debrided including a debridement of skin, subcutaneous tissue, muscle, and bone. The scarred subcutaneous tissue around the pin sites was released with a curette. Wounds were excised or sutured. The limbs were then cleaned and dressed. Limbs were then protected either with a cast, walker boot, or hinged knee brace depending on surgeon discretion. Follow-up was conducted after 2 weeks from the removal procedure.

Data collection/outcome measures

The surgeon recorded patient demographics including the use of preoperative pain medications (within the last week before removal); frame location (limb segment or joint); and frame complexity (number of rings and arches and number of wires and half-pins). The surgeon then prospectively assigned a grade of anesthetic adequacy provided during the removal process keeping the anesthetist blinded to the score: A, excellent sedation; B, good sedation; C, fair sedation; D, poor sedation-patient undermedicated, and moving around a lot. The anesthesiologist recorded sedative and analgesic doses given during the procedure; airway management and anesthetic technique; and frame removal time. Frame removal time began at the moment the removal began (after induction, prepping, draping, and intraoperative timeout) and ended when the postoperative dressing had been applied (excluding additional time for X-ray and casting or bracing applied after the initial dressing). The anesthetic needs of patients who were actively taking narcotics up to the time of frame removal (medicated) was compared to those for patients that had stopped narcotics at least 1 week before the procedure (non-medicated). The location and complexity of the frame used was compared between these two groups as well.

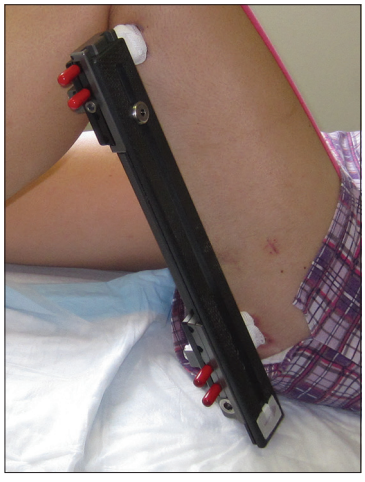

Figure 4: This is a typical monolateral frame used for lengthening over a nail

Statistical analysis

Descriptive statistics of the study population is reported as means and standard deviations (SD) for continuous variables. Frequencies and percentages are reported for discrete variables. Chi-square or Fisher's exact tests were used to compare differences in categorical variables between anesthesia groups and between patients who were and those who were not on any narcotic medication before surgery. Nonparametric Mann-Whitney U tests were used to evaluate differences in continuous variables between anesthesia groups. Independent samples-tests were used to compare the mean values of continuous data between preoperative narcotic drug usage groups. All analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA) with a critical as $P \leq 0.05$.

Results

Fifty-three patients had external fixators removed in the OR over a 7-month period. Frames were composed of an average of rings/arches (range 2–5), 3 half-pins (range 2–11), 2 olive wires (range 0–5), and 2 smooth wires (range 0–6). Thirty-eight patients (71.7%) had

Table 1: Patient demographics

	Patients (n=53), n (%)
Sex (female)	22/53 (42)
Weight (kg), average (range)	82.7 (50-153)
Preoperative narcotic use	29/53 (55)
Circular frame	49/53 (92)
Femur frame	9/53 (17)
Tibia frame	39/53 (74)
Foot/ankle frame	38/53 (73)
Forearm frame	1/53 (2)
Monolateral frame	4/53 (8)

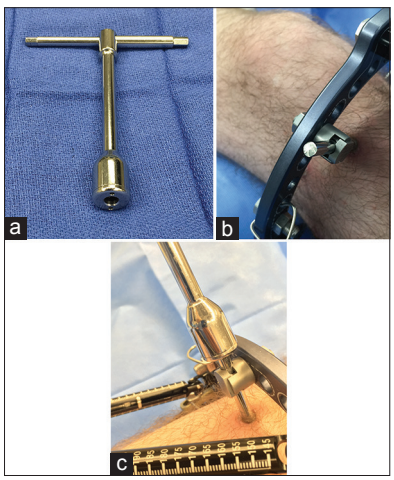

Figure 5: (a) The excalibur half pin extractor from orthofix can provide the torque needed to remove hydroxyapatite-coated pins after the pins have been trimmed (b) This half pin has been cut with a Harrington rod bolt cutter leaving a sharp edge with no way to grip it (c) The extractor is seen removing the cut pin with ease

Table 2: Anesthetic administered

Medication given	*n* (%)	Mean dose	SD	Minimum dose	Maximum dose
Sedatives: Midazolam (mg)	46 (87)	4.6	1.7	2.0	10.0
Sedatives: Propofol (mg)	50 (94)	218.9	163.6	25.0	700.0
Sedatives: Propofol infusion (max rate ml/h)		22.7	26.3	0.0	117.0
Sedatives: Propofol infusion (mcg/kg/min)		45.7	51.1	0.0	172.6
Analgesics: Fentanyl (mcg)	40 (75)	100.0	19.6	50.0	200.0
50 mg	2 (5)				
100 mg	37 (93)				
200 mg	1 (3)				
Analgesics: Ketamine (mg)	4 (8)	35.0	17.3	20.0	50.0
20	2 (50)				
50	2 (50)				

SD: Standard deviation

Table 3: Airway management

Airway and Anesthesia	*n* (%)
Airway: Nasal	7 (13)
Airway: Oral	1 (2)
Airway: Chin lift/jaw thrust	31 (58)
Anesthetic technique: MAC (IV sedation)	49 (92)
Anesthetic technique: Regional	1 (2)
Anesthetic technique: GA	3 (6)

MAC: Monitored anesthesia care, IV: Intravenous, GA: General anesthesia

Table 4: Anesthesia sedation score

Anesthesia grade	*n* (%)
A	38 (72)
B	10 (19)
C	4 (8)
D	1 (2)
A/B	48 (91)
C/D	5 (9)

A=Excellent, B=Good, C=Fair, D=Poor

2 ring frames, 11 patients (20.8%) had frames with 3–5 rings/arches, and 4 patients (7.5%) had monolateral frames removed [Table 1]. Surgical time for removal of the fixator and debridement of the pin sites (exclusive of postoperative radiography, casting, or bracing) averaged 13.4 min (SD 5.6 min, range 7–40 min).

Fifty-one patients (96.2%) were managed with intravenous (IV) sedation and monitored anesthesia care (MAC). Most patients received a combination of several sedatives and analgesics. The typical medications used were midazolam, propofol, and fentanyl. Ketamine, hydromorphone, and ketorolac were used less frequently. Few patients received all of these, but most (41 of 53, 77.4%) received at least three drugs. On average, 4 mg of midazolam (range 0–10 mg), 207 mg of propofol (range 0–700 mg), and 75 mcg of fentanyl (range 0–200 mcg) were administered [Table 2]. Airway management required the use of a nasopharyngeal airway (nasal trumpet) in 7 patients (13.2%), an oropharyngeal airway in 1 (1.9%), a head tilt/chin lift/jaw thrust maneuver in 31 (58.5%). In all, 36 patients (68%) required active management of the airway. One patient (1.9%) received regional anesthesia (spinal) for iliac crest bone marrow aspiration and injection at the time of frame removal. Three patients (5.7%) underwent general endotracheal anesthesia due to airway concerns [Table 3].

Anesthesia was graded as good-to-excellent (group AB) in 91% and unsatisfactory to poor (Group CD) in 9% of cases [Table 4]. Both AB and CD groups received similar types and dosages of sedatives. The CD group received significantly higher (P = 0.02) dosages of analgesics (fentanyl) when compared with the AB group [Table 5]. The CD group was not more complicated than the AB group. There was no difference in the percentage of patients taking narcotic medication before frame removal in groups AB and CD; however, CD patients were found to be significantly heavier than AB patients [Table 6].

Those patients who were using narcotic medication for pain in the week before frame removal were significantly lower in body weight (76.0 kg vs. 90.7 kg, P = 0.007) than those who were not. When these two groups were compared no significant difference was found in the amount of midazolam (3.9 mg vs. 4.0 mg, P = 0.818), propofol (203.3 mg vs 210.5 mg, P = 0.877) or ketamine (3.1 mg vs. 2.1 mg, P = 0.721) used between the two groups. The medicated group was administered significantly less fentanyl (62.1 mcg vs. 91.7 mcg, P = 0.020). Airway management and anesthetic technique were similar between the groups. The preoperatively medicated group had significantly more frames located about the ankle and foot (82.8% vs. 58.3%, P = 0.049) than the preoperative, nonmedicated cohort. Frames were more complex (three or more rings) in the preoperatively medicated patients (34.5% vs. 4.2%, P = 0.018) [Table 7].

Discussion

Prior studies have looked critically at external fixator removal, without the use of HA-coated pins, finding that

Table 5: Medications administered by anesthesia grade

Variable	Grade						*P*
	A/B			C/D			
	n	Mean or *n*	SD or %	*n*	Mean	SD	
Sedatives: Midazolam (mg)	41	4.6	1.8	5	4.6	1.8	0.983
Sedatives: Propofol (mg)	45	217.7	167.8	5	230.0	133.8	0.662
Sedatives: Propofol infusion (max rate ml/h)	45	23.6	26.8	5	15.0	21.2	0.548
Sedatives: Propofol infusion mcg/kg/min	45	48.0	52.4	5	24.5	34.3	0.355
Analgesics: Fentanyl (mcg)	37	97.3	11.5	3	133.3	57.7	0.021
50	37	2	5%	3	0	0%	0.002
100	37	35	95%	3	2	67%	
200	37	0	0%	3	1	33%	
Analgesics: Ketamine (mg)	4	35.0	17.3	0			NA
20	4	2	50%	0	0	0%	NA
50	4	2	50%	0	0	0%	

SD: Standard deviation, NA: Not available

Table 6: Complexity AB versus CD groups

Variable	A/B (*n*=48)		C/D (*n*=5)		*P*
	Mean	SD	Mean	SD	
Weight (kg)	80.9	20.2	99.6	11.0	0.022
Removal time (min)	13.5	5.8	12.2	3.2	0.722
Medicated=taking preoperative narcotic daily (*n*)	27	56.3%	2	40.0%	0.649
Airway: Nasal (yes/no)	7	14.6%	0	0.0%	1.000
Airway: Oral (Y/N)	1	2.1%	0	0.0%	1.000
Airway: Chin lift/jaw thrust (Y/N)	27	56.3%	4	80.0%	0.389
Anesthetic technique: MAC (IV sedation)	46	95.8%	5	100.0%	1.000
Anesthetic technique: Regional	1	2.1%	0	0.0%	1.000
Anesthetic technique: GA	3	6.3%	0	0.0%	1.000
Frame location: Femur	9	18.8%	0	0.0%	0.574
Frame location: Tibia	34	70.8%	5	100.0%	0.309
Frame location: Ankle/foot	34	70.8%	4	80.0%	1.000
Frame location: Foot	16	33.3%	0	0.0%	0.307
Frame location: Humerus	0	0.0%	0	0.0%	NA
Frame location: Forearm	1	2.1%	0	0.0%	1.000
Frame location: Hand	0	0.0%	0	0.0%	NA
Frame size					
Monolateral	4	8.3%	0	0.0%	0.336
2 rings	33	68.8%	5	100.0%	
3+ rings	11	22.9%	0	0.0%	

SD: Standard deviation, NA: Not available, MAC: Monitored anesthesia care, IV: Intravenous, GA: General anesthesia

removal without anesthesia was well tolerated.[17,18] While we do remove 1.8-mm tensioned wires in the office routinely without anesthesia, the HA-coated pins bind to the bone and require removal under sedation. HA-coated pins and the excellent, sustained fixation they provide have been an important advance in external fixation, offering better frame stability, less loosening, and lower rates of pin infection.[14-16,22] The results of the present study document the anesthetic requirements for external fixator removal in the era of HA-coated half-pins. IV sedation/MAC used to mitigate the painful stimuli provoked by the removal of the frame elements and pin site debridement demands a delicate balance to achieve patient comfort, spontaneous breathing, and airway maintenance. This study strove to document an anesthesia-assisted frame removal protocol, analyze the adequacy of this approach, and look at the effects of chronic narcotic use on the protocol.

There are several limitations of this study. While we demonstrated that significant anesthetic dosages are administered in the OR to comfortably remove external fixators using HA-coated pins, we cannot prove that we were treating only pain. Light sedation can make some patients combative which requires deeper sedation to calm them. In these cases sedation extra sedation is used not to treat pain but instead to calm the patient. There was no attempt to compare different protocols with varying drug

Table 7: Preoperative narcotic analysis

	Preoperative narcotics (medicated)		No preoperative narcotics (nonmedicated)		*P*
	Mean	SD	Mean	SD	
Weight (kg)	76.0	16.7	90.7	21.4	0.007
Midazolam (mg)	3.9	2.1	4.0	2.4	0.818
Propofol (mg)	203.3	168.8	210.5	170.3	0.877
Fentanyl (mcg)	62.1	54.4	91.7	28.2	0.020
Ketamine (mg)	3.1	10.4	2.1	10.2	0.721
Ankle/foot frame (*n*)	24	82.8%	14	58.3%	0.049
Frame size-3 more more rings (*n*)	10	34.5%	1	4.2%	0.018

SD: Standard deviation

dosages as the independent variable, so patients may have been over sedated. The small numbers of patients ($n = 5$) that were felt to be suboptimally sedated during the removal procedure (the CD group) made statistical analysis less precise. The creation of a medicated group, defined by the use of oral narcotics the week before the frame removal, as a surrogate for defining a chronic pain cohort could affect the conclusions. The anesthetic adequacy grading system was subjective and should be further studied to assess its reliability.

The majority of patients was treated with IV sedation only (92.4%) and most required some form of mild airway management (68%). Sedation consisted of a cocktail of several medications including multiple combined sedatives (midazolam and propofol) and analgesics (fentanyl and/or ketamine). Due to the fact that pin removal and pin site debridement generate significant pain, our anesthesia department feels that lower doses of a combination of medications generates the intended anesthetic effect while minimizing side effects such as sleep apnea. A monomodal sedation approach using propofol, for example, would require large doses and aggressive airway management including intubation. The decision of whether to intubate the patient was also left to the professional opinion of the anesthesia team to ensure safety. One patient had iliac crest aspiration and injection of bone marrow aspirate into the healing osteotomy site at the time of frame removal and was treated with spinal anesthesia. This patient was not excluded from the study since this was a consecutive series.

The adequacy of anesthesia was assessed by the operating surgeons and rated their perception that the patient was not reacting to pain during the removal process. The vast majority (91%) of patients were rated by the surgeon as having good to ideal anesthesia during the removal and debridement process. The five patients (9%) who were felt to be poorly anesthetized reacted to the pain of unscrewing the half pins by moving to varying degrees during the procedure. Data analysis shows that these patients received the same dosages of sedatives and higher dosages of fentanyl than the well-controlled group confirming that the CD group patients were not given less medication. The CD group patients did have a higher average body weight which may have lessened the effect of the medications and indicate that these patients need higher sedative dosages as well and analgesics within the limits of safety. The heavier patients had worse airways requiring the anesthesiologist to use a lighter sedation effect to prevent the need for difficult airway management. Further analysis showed that the CD group patients were not narcotic tolerant; there was no difference in the distribution of medicated and non-medicated patients in the AB and CD groups.

Our analysis of the medicated (those patients taking narcotics through the week before surgery) and nonmedicated (those who were no longer taking narcotics) cohorts demonstrated a paradoxically lower dosage of fentanyl used in the medicated group. The medicated group had a lower body weight and tended to have ankle and foot frames and more complex-larger frames. This data suggests that the complex foot and ankle reconstructive surgery is correlated with chronic pain requiring narcotics throughout treatment. The removal surgery was done with less analgesia (less fentanyl), perhaps due to lower body weight, without any impact on surgeon perceived anesthesia control as the same percentage of patients were scored as AB in both groups. There was no intentional effort made to give these opioid-experienced patients less anesthesia.

Conclusion

Anesthesiologists administer the least amount of medication to achieve the goal of frame removal without significant pain. The OR provides an ideal environment for safe removal of the external fixator, debridement of the pin sites, radiographic examination, and casting without patient movements.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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