Assessment of medial meniscus extrusion as an indirect sign of tear on ultrasound with emphasis on the added value of standing position

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Introduction
Ultrasound (US), besides being a widely available, noninvasive, relatively inexpensive imaging modality, allows dynamic and weight-bearing scans, hence encouraging its utilization in various musculoskeletal applications. This study is to assess the reliability of US in supine and standing (weight-bearing) positions to detect medial meniscus extrusion as an indirect sign of tear.

Patients and methods
This observational prospective study included 103 patients: 48 females and 55 males; mean age: 36.82 years. The extrusion was measured on supine and standing US. The included patients were classified into two groups according to the MRI diagnosis of tear. Statistical analysis was performed and *P* value less than 0.05 was considered significant. Receiver-operating characteristic curve was done to reach a cutoff value for extrusion as a sign of tear.

Results
This study included 103 patients: 48 females and 55 males; mean age: 36.82 years. The medial meniscus extrusion was measured using US in supine and standing positions. The included patients were classified into two groups according to the presence or absence of tears on MRI. Forty-five (43.68%) patients had medial meniscal tears (horizontal, vertical, branching, radial, root, and bucket-handle tears). The measured extrusion in supine and standing positions, as well as the difference between the measurements in the two groups, all showed a significant *P* value of 0.001. In patients with meniscal tears, the mean extrusion was 2.5±0.65 and 3.82±0.84 mm in supine and standing positions, respectively. The extrusion in standing position with a cutoff value more than or equal to 3.3 mm showed specificity (96.55%), positive predictive value (93.8%), and accuracy (83.5%) for detection of tear.

Conclusion
US is reliable in determining medial meniscal extrusion as an indirect sign of tear. US in standing position yields better diagnostic accuracy compared with supine position.

Keywords:
extrusion, knee, medial meniscus, meniscus tear, standing ultrasound, weight-bearing ultrasound

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Introduction

The menisci are C-shaped fibrocartilaginous structures that have an essential role in maintaining knee joint congruence. The structural integrity of menisci helps to avoid and delay osteoarthritis (OA) through absorbing shock and distribution of axial loading [1,2]. MRI is the modality of choice for the assessment of knee pathologies and particularly meniscal tears with high diagnostic accuracy [1–5].

Medial meniscus extrusion is described as extension of the peripheral edge of the meniscus beyond the edge of tibial margin of the tibiofemoral compartment. It is a result of weakening or loss of integrity of the collagen bundles of the meniscus which normally resist axial loading. Extrusion is regarded as an indirect sign of meniscus tear and is highly prevalent with posterior root tears, complex and large radial tears [1,6–9]. OA, cartilage degeneration, and joint malalignment were also described as contributing factors to meniscus extrusion [10].

The use of ultrasound (US) imaging for the diagnosis of menisci injuries is increasingly investigated and there are promising results regarding its diagnostic accuracy [11–16]. It has been proved reliable for diagnosing meniscus extrusion [17]. In comparison to MRI, US is

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widely available, noninvasive, relatively inexpensive, and less time consuming. More interestingly, the feasibility of dynamic and weight-bearing imaging on US makes it a popular investigative method in musculoskeletal imaging with variable applications [17–20].

The purpose of this study is to assess the reliability of US in supine and standing weight-bearing positions to detect medial meniscus extrusion as an indirect sign of underlying meniscal tears.

Patients and methods

The patients who visited the rheumatology outpatient clinic at our institute between June and December 2018 were interviewed at the clinic for their age, sex, occupation, activity, pain onset, duration, and severity. Assessment of passive and active range of movement was done. We included 103 patients (48 females and 55 males, age range: 18–70 years, mean age: 36.82). An informed medical consent was obtained from the patients. The study design is observational analytic and has been approved by the ethics committee at our institute in compliance with Helsinki Declaration.

Inclusion criteria

We included patients complaining of pain along the medial joint line, tenderness, difficulty in flexion, or extension.

Exclusion criteria

Patients younger than 15 years old and patients with a history of knee surgery or arthroscopic intervention to medial meniscus were excluded.

Ultrasound

US scan of the painful knee joint was arranged for all the included patients. For patients who had bilateral knee pain, we selected the more painful joint. The scan was performed using US machine GE Logiq pro6 (San Jose, California, USA) and Toshiba Xario 100 (Tustin, California, USA) with a linear high frequency probe (10–12 MHz). The US was performed by a specialized radiologist (3 years of experience). The patients were examined in both supine and standing (weight-bearing) positions. The medial meniscus was assessed at the medial compartment of the knee with the probe in a longitudinal direction and the extrusion measured with the patient in the supine with the knee flexed ~20°–30°. Then the patient was asked to stand (weight-bearing) and the medial meniscus extrusion was again assessed with the probe in longitudinal direction. The extrusion was measured as the distance from the outermost edge of the medial meniscus to a line connecting the femoral and tibial cortices in both positions. At the time of US scan, the operator did not have the information of MRI diagnosis of meniscus tear. The US scan measurements were documented for all patients and grouping was done later after collection of both US and MRI data.

MRI

An MRI was booked for the included patients on the same day of US scan. The MRI scan was done using a high field-strength scanner: Philips scanners Achieva, 1.5 Tesla MRI scanner (Achieva, Philips Medical Systems, The Netherlands). A dedicated knee coil was used. The following sequences were done: sagittal T2, proton-density weighted images, coronal short T1 inversion recovery (STIR), and axial T2-weighted images. The scan parameters are slice thickness 4 mm, slice gap 4 mm, matrix 256/192 or 512/224, and field of view ranged from 12 to 16 cm. The average duration time of the examination was around 15–20 min. The MRIs were transferred to a workstation using the Digital Imaging and Communications in Medicine (DICOM) format. The MRI were interpreted by a radiology trainee (3 years of experience) and two musculoskeletal consultant radiologists (12 and 20 years of experience). They were blind to each other's interpretation and for controversial opinion, a consensus was reached after discussing the images. Meniscal tear was diagnosed by one or more of the following criteria, if confirmed on at least two images:

(1) Deformed meniscal outline (sagittal images: distorted normal appearing bow tie of the body and triangular appearance of the horns. Coronal images: distorted normal quadrilateral appearance of the horns and triangular appearance of the body).
(2) Meniscal intrasubstance band of high signal, disrupting any of its surfaces.
(3) Absent root attachment on sagittal, coronal, and axial images.

Statistical analysis

The included patients were classified into two groups according the presence or absence of medial meniscus tear on MRI. The measured values of the medial meniscal extrusion in supine and standing positions obtained from the US examination were correlated to the diagnosis of tears. The results are expressed as mean ±SD or number (%). Comparison between categorical data was performed using χ^2 test or Fisher's test instead if cell count was less than 5. Test of normality, Kolmogorov–Smirnov test, was used to measure the distribution of data. Accordingly, comparison between normally distributed data was performed using unpaired *t* test. In not normally distributed data, comparison between data was performed using Kruskal–Wallis analysis of variance test. Receiver-operating characteristic test was used to discriminate between the patients with and without tears and there relation to extrusion on US in the two positions. We calculated diagnostic indices [sensitivity, specificity, positive predictive value (PPV), and negative predictive value and accuracy]. Statistical Package for the Social Sciences (SPSS) [SPSS, International Business Machines Corporation (IBM), Armonk, New York, USA] computer program (version 19 Windows) was used for data analysis. *P* value less than or equal to 0.05 was considered significant.

Results

The included patients were classified into two groups according to the presence or absence of medial meniscus tear on MRI: group A included 45 (43.68%) patients with tears, 22 females and 23 males, mean age: 33.16 years. Group B included 58 (56.3%) patients without tears, 26 females and 32 males with a mean age of 41.53 years.

In group A (patients with meniscal tears), the measured value of extrusion ranged from 1.3 to 4.2 mm in supine and from 2.5 to 6.5 mm in standing. The mean extrusion was 2.5±0.65 and 3.82±0.84 mm in supine and standing, respectively, and hence the difference in extrusion was 1.32±0.70 mm. In group B (patients without meniscal tears), the measured value of extrusion ranged from 0.9 to 3.2 mm in supine and from 1.5 to 3.5 mm in standing. The mean extrusion was 1.95±0.49 and 2.71±0.43 mm in supine and standing, respectively, and hence the difference in extrusion was 0.75±0.43 mm. A statistically significant difference (*P*=0.001) was found between the mean values of meniscal extrusion in both study groups (Table 1).

The menisci tears as diagnosed by MRI included horizontal tear (*n*=23) (Fig. 1), root tear (*n*=11) (Fig. 2), branching tear (*n*=4), radial tear (*n*=4) (Fig. 3), bucket-handle tear (*n*=2), and vertical tear (*n*=1).

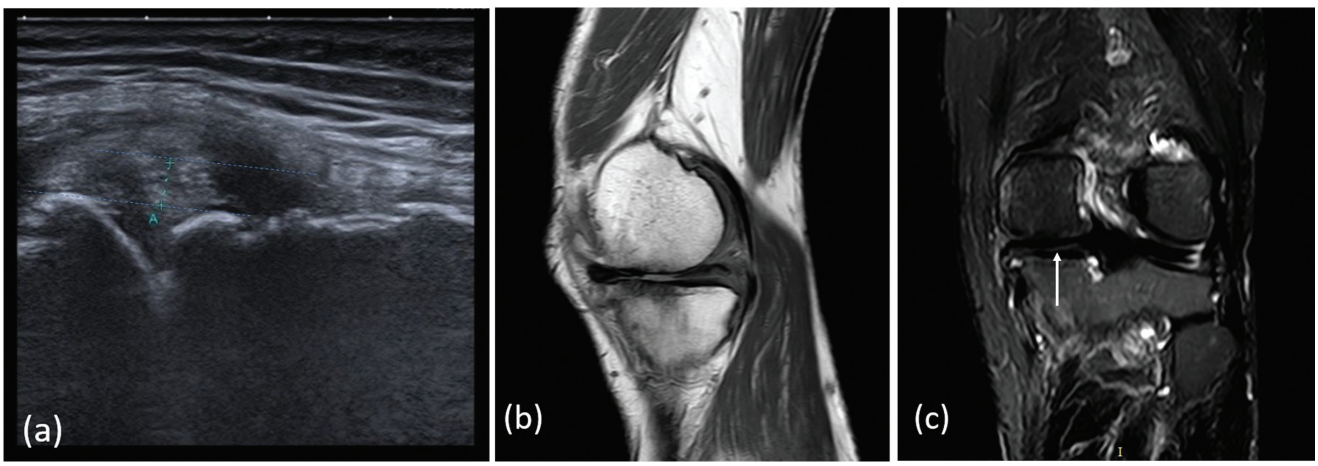
We used receiver-operating characteristic curve analysis to reach a cutoff value for medial meniscus extrusion in supine and standing positions and the difference in between the two positions. The sensitivity, specificity, PPV and negative predictive value, and diagnostic accuracy are listed in Table 2. In standing position, a cutoff value for extrusion at or

Table 1 Mean values of meniscal extrusion on ultrasound in both study groups

Extrusion	Supine US (mean±SD)	Standing (weight bearing) US (mean ±SD)	Difference (mean±SD)
Group A (*n*=45)	2.50±0.65	3.82±0.84	1.32±0.70
Group B (*n*=58)	1.95±0.49	2.71±0.43	0.75±0.43

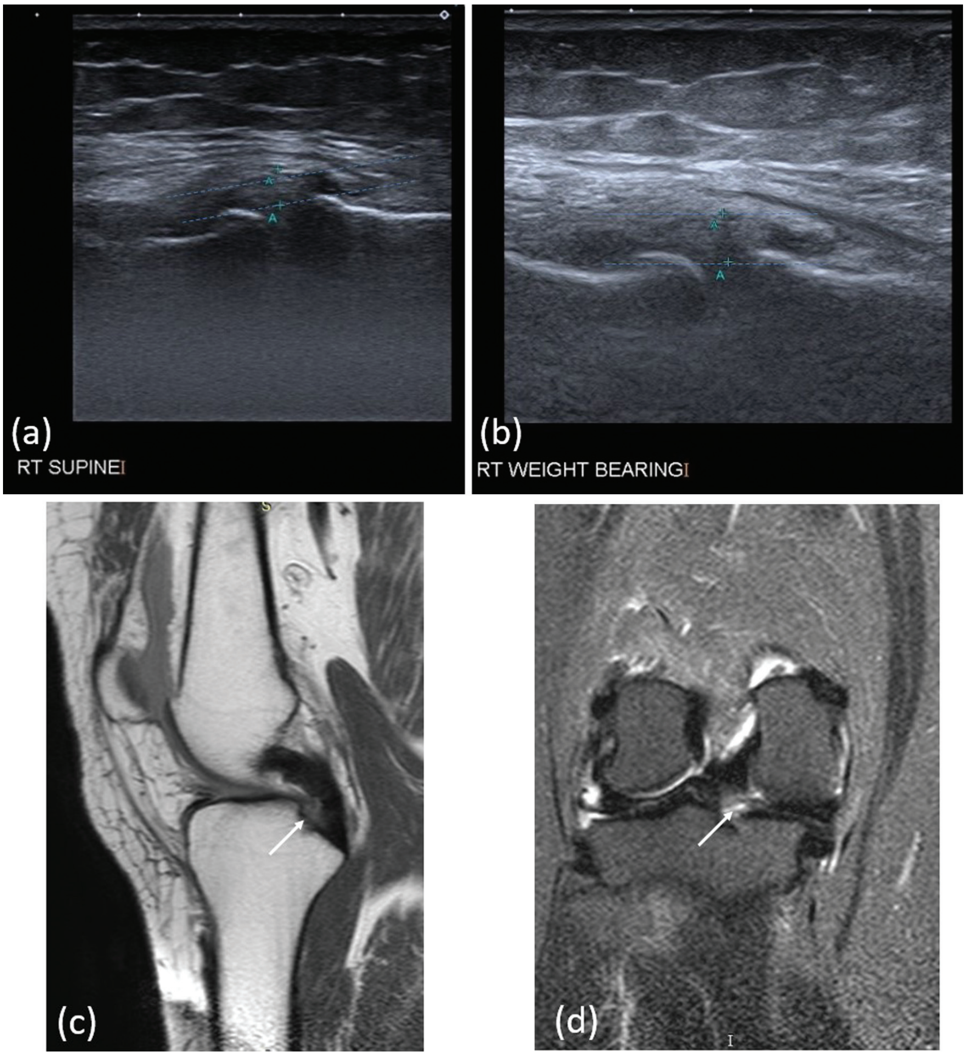
US, ultrasound. *P* value=0.001.

Figure 1



A 70-year-old male patient complaining of left knee long-standing pain. Ultrasound images (a) in standing position, showing 3.5 mm extrusion of the echogenic medial meniscus. MRIs, (b) sagittal PD, and (c) coronal STIR showing medial meniscus horizontal tear. The tear appears as a high signal horizontal band along the posterior horn of the medial meniscus (arrow in c); disrupting the articular surface with loss of the normal triangular appearance of the posterior horn on the sagittal image. PD, proton density.

Figure 2



A 40-year-old female patient complaining of right knee pain of sudden onset 2 days ago. US scan in supine position (a) showing medial meniscal extrusion measured 3.6 mm and in standing position, (b) measured 4.2 mm. MRI sagittal PD images (c) shows absent root (arrow) at its expected site; close to the posterior cruciate ligament and coronal STIR (d) also shows root tear at its tibial insertion site (arrow). PD, proton density; US, ultrasound.

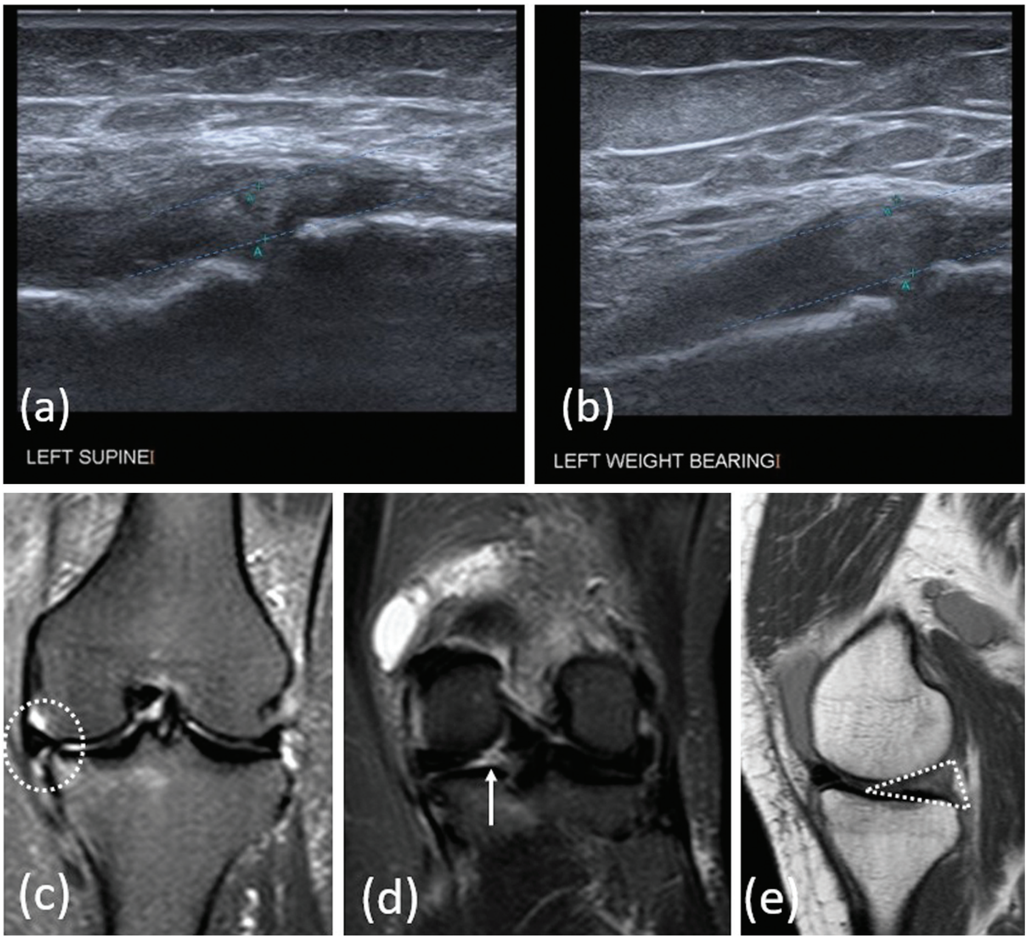
greater than 3.3 mm demonstrated high specificity (96.55%), PPV (93.8%), and good diagnostic accuracy (83.5%) for diagnosis of a medial meniscus tear (Fig. 4).

Discussion

Meniscus extrusion is defined as extension of the meniscus peripheral edge for 3 mm or more beyond the edge of the tibial plateau. It is easily detected and can be measured on coronal MRI. It is commonly associated with root tears as well as complex tears, large radial tears, and severe degeneration [1,3,6,7,9,21]. In one study, authors concluded that extrusion beyond 2 mm should be considered significant and that most of menisci tears that required treatment showed extrusion between 2 and 3 mm [8]. Extrusion by itself is a sign of weakened circumferential collagen bundles and whether related to a tear or severe degeneration and laxity, its presence implies reduced resistance to hoop strain and less buffer of axial load. This is expected to accelerate cartilage degeneration and OA [8,22,23].

Currently, there is no consensus or clear guidelines to include US in the diagnosis of menisci injuries. However, the wide availability, relatively short scan time, and low cost of using US encourages studying its reliability, diagnostic accuracy, and cost effectiveness. Lately most publications show encouraging results in contrast to older ones [11,13,14,24]. Meta-analysis reviews show good US diagnostic accuracy for menisci injuries explained by improved US image resolution, operators skills in musculoskeletal US, and the use of linear array probes [13]. Interestingly, in one study the patients' demographics, BMI, and physical activity did not influence the results [12]. In

Figure 3



A 56-year-old female patient complaining of left knee pain following recent trauma and swelling of the knee joint. (a) Supine US showing extrusion of echogenic medial meniscus measured 4.0 mm and in standing US (b) measured 6.5 mm. MRI coronal STIR (c and d), with the body of medial meniscus extruded (dashed circle in c) and a radial tear is seen involving its posterior root attachment (arrow in d). Sagittal PD image (e) showing ghost meniscus signs (dashed triangle) corresponding to the radial tear. PD, proton density; US, ultrasound.

Table 2 Diagnostic evaluation of the different positions to assess meniscal extrusion on ultrasound

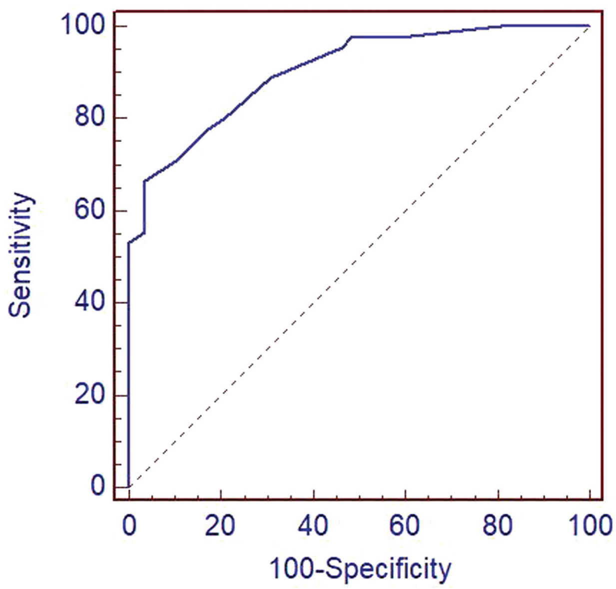
	Extrusion on supine	Extrusion on standing	Difference in extrusion
Cutoff	>2.0	>3.3	>0.9
Area under ROC	0.752	0.904	0.740
Sensitivity	77.78%	66.67%	66.67%
Specificity	67.24%	96.55%	67.24%
PPV	64.8%	93.8%	61.2%
NPV	79.6%	78.9%	72.2%
Accuracy	71.85%	83.50%	66.99%

NPV, negative predictive value; PPV, positive predictive value; ROC, receiver-operating characteristic.

another study, the diagnostic accuracy for US was better for patients younger than 30 years [15].

For assessment of meniscus extrusion in particular, a previous study demonstrated an excellent diagnostic performance of US, compared with MRI as a reference,

Figure 4



ROC curve of medial meniscus extrusion measurements using US in standing position. ROC, receiver-operating characteristic; US, ultrasound.

in the detection of medial meniscus extrusion. The authors concluded that US is reliable in quantitative and semiquantitative assessment of meniscus extrusion [17].

Because in standing, axial loading and physical weight bear increase, a corresponding increase in meniscus extrusion is expected. In the literature, two published studies assessed medial meniscus extrusion using US in supine and weight-bearing positions. These studies concentrated their work on OA patients, irrelevant to the diagnosis of meniscus tear. Their results demonstrated a significant increase in extrusion on weight-bearing position as well as in the context of OA [18,20]. In this study, we measured the values of medial meniscus extrusion on both supine and standing positions to find their significance relevant to the presence of meniscus tear. The results demonstrated significantly higher mean values of meniscal extrusion in the group of patients who had tears, on both supine and standing positions. These results are consistent with the published data as regards the reliability of using US to assess meniscus extrusion and additionally reenforce the value of extrusion as an indirect sign of tear. The results also highlight the additional benefit of US scan in standing position to exploit weight bearing and enhance extrusion. The statistical analysis reached an extrusion cutoff value more than or equal to 3.3 mm to detect tear using US in standing position with high specificity and PPV. This value fits in the ranges published in previous research studies [1,8].

One of the present study limitations was the nonhomogeneous presentation of different types of tears, with predominance of horizontal tears. So, we were not able to correlate the results to the tear type. The lack of arthroscopy results to confirm the final diagnosis of tear is also considered a limitation. This was because the included patients were from the outpatient clinic. However, we used MRI as our reference which is known for its excellent diagnostic accuracy in medial meniscus tears and in some publications is considered as a reference standard [17]. We also strictly applied the signs of meniscal tear on at least two MRI on at least two MR images and relied on expertise consensus to reach a final diagnosis of tear.

Conclusion

US is reliable in determining medial meniscal extrusion as an indirect sign of an underlying tear. Performing US in standing position allows for weight bearing and a subsequent increase in the measured extrusion value is seen, together with better diagnostic accuracy indices compared with that in supine position. Our results are encouraging to promote US scanning of the patients in standing position when meniscal assessment is required.

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Conflicts of interest

There are no conflicts of interest.

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