Value of diffusion-weighted magnetic resonance imaging in the characterization of small solid renal lesions

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Aim of the study
Our aim was to assess the value of diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) measurement for the characterization of small solid renal lesions.

Patients and methods
We prospectively evaluated 30 patients (18 men and 12 women). Their age ranging from 18 to 65 years (mean age of 49.6±12.9). They were examined by conventional MRI and DWI with b factors of 0, 600 and 1000 s/mm2. Mean ADC values of the normal renal parenchyma, benign, malignant small solid renal lesions were calculated

Results
The mean ADC value of normal renal parenchyma was significantly higher that of benign and malignant lesions. No statistical significance noted between the mean ADC values of benign and malignant renal lesions (*P* value=0.5). Among malignant lesions, the mean ADC value was highest in the RCC lesions (1.4±0.22) and lowest in the lymphoma lesions (0.679±0.08) showing statistical significance (*P* value=0.0001). The mean ADC values of RCC and TCC showed no statistical significance, whereas there was statistical significance was noted between RCC and pyelonephritis (*P* value=0.0004) , RCC and Angiomyolipomas (*P* value=0.0001), lesions.

Conclusion
DWI is a fast sequence that can be easily added to a routine MR imaging protocol. DWI is notably valuable in lesion detection and evaluation when gadolinium contrast medium cannot be administered. However, due to the overlap of ADC values between benign and malignant lesions, it cannot be used as a single diagnostic tool and should be concurrently interpreted in conjunction with conventional MRI for optimal characterization of renal lesions.

Keywords:
benign, diffusion-weighted imaging, malignant, renal lesions, small, solid

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Introduction

In daily practice, for various abdominal complaints, the incidental detection of small (≤3 cm) solid renal masses has increased because of utilization of widely available ultrasonography (US) equipment and computed tomography scanners [1]. The majority of these masses are malignant, whereas 20–25% of them are benign [2,3].

In deciding on a therapeutic approach for different small renal lesions, it is crucial to differentiate malignant from benign ones [4] as the choice of treatment varies between reassurance of the patient, radiological follow-up, ablative procedures, partial nephrectomy, and radical nephrectomy [5].

Percutaneous renal biopsy may be recommended for accurate characterization of small renal lesions; however, this procedure has some limitations as it is not universally available, and results in procedural complications and potential sampling errors [6].

There is a need for methods providing better and accurate characterization. Diffusion-weighted imaging (DWI) is an MRI technique that depicts molecular diffusion differences caused by the random and microscopic motion of the molecules, known as the Brownian motion. It is useful in tumor differentiation as the apparent diffusion coefficient (ADC) measurements reflect variations in water diffusion of the tumor and the adjacent tissue, providing additional information that is not available from conventional images [7].

The aim of this study is to assess the value of DWI and ADC measurements for the characterization of small solid renal lesions.

Patients and methods

Patients

Over a 1-year period, 30 patients (18 men and 12 women) were prospectively enrolled in this study; their age ranged from 18 to 65 years (mean: 49.6±12.9 years). All patients presented with at least one small renal lesion less than or equal to 3 cm by US and/or computed tomography.

The study protocol was approved by the Hospital Scientific and Ethical Committee and all patients agreed to participate in the study.

Methods

Imaging protocol

All examinations were performed using a 1.5 T MRI scanner (Gyroscan Achieva; Philips Medical Systems, The Netherlands) equipped with a phased array body coil.

The standard protocol included the following sequences: respiratory-triggered axial and coronal T2-weighted (T2WI) Fast Spin Echo (FSE) sequences, axial T2WI spectral presaturation with inversion recovery with fat suppression, axial T1-weighted (T1WI) fast low-angle shot (FLASH) GRE sequence, and T1WI dual-echo in-phase and out-of-phase sequences.

A DWI was obtained with a single-shot spin echo-planner sequence before contrast material administration; DWI was acquired during breath-hold at b values of 0, 600, and 1000 s/mm^2.

Finally, dynamic contrast-enhanced images were acquired before and after an intravenous injection of a bolus of 0.1 mmol/kg of gadopentetate dimeglumine-DTPA (Magnevist; Schering, Berlin, Germany), followed by 20-ml saline flush. Three-dimensional fat-saturation T1WI dynamic contrast-enhanced sequences were performed during suspended respiration at baseline (precontrast), 30, 90, and180 s after the injection of the contrast material.

Gadolinium was not administered in two patients diagnosed with pyelonephritis because of their impaired renal function.

Imaging analysis

All MRI were transferred to an independent workstation (Philips MR Extended Workspace, software version 2009; Philips). Conventional nonenhanced and contrast-enhanced images were first reviewed. The morphological features of each lesion were recorded including the number, site, size, shape, as well as the signal characteristics, and enhancing pattern.

Diffusion-weighted imaging quantitative analysis

ADC maps were generated automatically using already available algorithms. The DWI, including the images obtained with *b* values of 0, 600, and 1000 s/mm^2, were reviewed together. Values of ADC maps were measured for a *b* value of 1000 s/mm^2 using the circumferential region of interest. Region of interests were placed at the center of the lesion, drawn as wide as possible, with the exclusion of necrotic portions and lesion margins.

Data collection and reference standard

The standard of reference was the pathological analysis obtained from US-guided biopsy and from the known diagnostic published criteria obtained using conventional MRI, clinical, and imaging follow-up in the pyelonephritis and angiomyolipoma (AML) cases.

Statistical analysis

The statistical package for the social sciences software (SPSS, release 21 version for Mac; SPSS Inc., Chicago, Illinois, USA), was used for statistical calculations. Data were expressed as mean±SD or number and percentage. Comparison between the mean values of ADC in different lesions was performed using Student's *t*-test. A *P* value less than or equal to 0.05 was considered significant and a *P* value less than 0.01 was considered to be highly significant.

Results

Lesion characteristics and conventional magnetic resonance imaging

Fifty small solid renal lesions in 30 patients were evaluated in the study. The final diagnoses of renal lesions included 29 (58%) malignant lesions and 21 (42%) benign lesions. Malignant lesions include Renal Cell Carcinoma (RCC) (*n*=13, 26%), Transitional Cell Carcinoma (TCC) (*n*=3, 6%), and lymphoma (*n*=13, 26%). Benign lesions include AML (*n*=9, 18%) and pyelonephritis (*n*=12, 24%). The final diagnosis was pathologically confirmed in the RCC, TCC, and lymphoma cases.

The signal intensity of the lesions on T1WI, T2WI, and fat-suppression T1 images was recorded. The signal intensity of the RCC and TCC lesions

Table 1 Apparent diffusion coefficient values of different groups of renal lesions in the study

Lesions	Number of patients	Lesions [*n* (%)]	Range of ADC value	Mean ADC value
Malignant	20	29 (58.00)	0.58–1.88	1.07±0.39
RCC	13	13 (26.00)	1.12–1.88	1.4±0.22
TCC	3	3 (6.00)	1.15–1.45	1.26±0.1
lymphoma	4	13 (26.00)	0.58–0.80	0.679±0.08
Benign	10	21 (42.00)	0.64–1.38	1.02±0.2
Pyelonephritis	5	9 (18.00)	0.67–1.24	0.966±0.18
AML	5	12 (24.00)	0.63–1.38	1.06±0.21

ADC, apparent diffusion coefficient.

showed low T1 and high T2 signal intensity, with 56% of the lesions showed homogenous enhancement after contrast administration. All lymphoma lesions (n=13) showed iso to low signal on T1WI and T2WI with homogenous contrast enhancement.

In pyelonephritis, the lesions showed low T1, high T2 signal intensity and heterogeneous enhancement. The nine AML lesions showed mixed high and low signal intensities on T1WI and T2WI and showed signal decrease at the T1 fat-suppression sequence.

Diffusion-weighted imaging and mean apparent diffusion coefficient value

All lesions showed restricted diffusion. ADC values of normal renal parenchyma, different lesions, and comparison between ADC values of different groups were recorded (Tables 1 and 2).

The mean ADC value of normal renal parenchyma (2.1 $\pm 0.18\times10^{-3}$ mm^2/s) was higher than that of benign and malignant lesions ($P<0.005$).

There was no statistical significance between the mean ADC values of benign ($1.02\pm0.2\times10^{-3}$ mm^2/s) and malignant renal lesions ($1.07\pm0.39\times10^{-3}$ mm^2/s) (P=0.5).

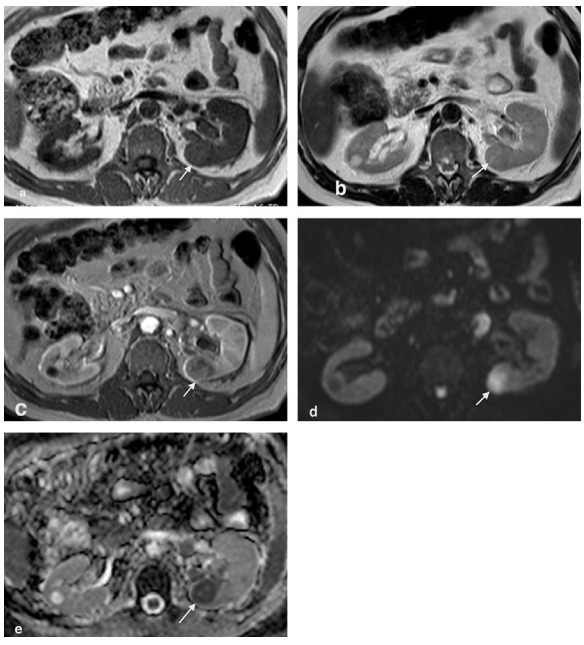
Among the malignant lesions, the mean ADC value was the highest in the RCC lesions (1.4 $\pm 0.22\times10^{-3}$ mm^2/s) (Fig. 1) and the lowest in the lymphoma lesions ($0.679\pm0.08\times10^{-3}$ mm^2/s) (Fig. 2), showing a statistically significance difference between the two groups (P=0.0001).

The mean ADC values of RCC and TCC (Fig. 3) showed no statistical significance (P=0.2), whereas there was a statistically significant difference between the mean ADC values of RCC and pyelonephritis lesions (Fig. 4) as well as between RCC and AML lesions (Fig. 5) (P=0.004).

Table 2 Comparison between the mean apparent diffusion coefficient values of different groups in the study

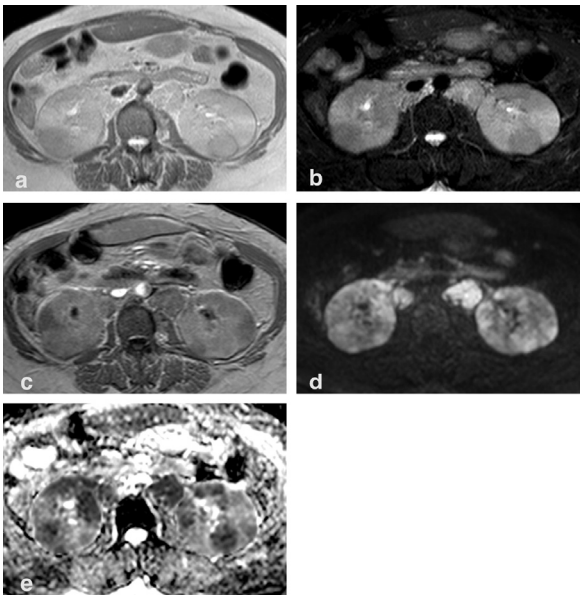
		P value
Normal renal parenchyma	Benign	
2.1±0.18	1.02±0.2	0.002
Normal renal parenchyma	Malignant	
2.1±0.18	1.07±0.39	0.018
Benign	Malignant	
1.02±0.2	1.07±0.39	0.2
RCC	TCC	
1.42±0.22	1.26±0.16	0.2
RCC	Lymphoma	
1.42±0.22	0.679±0.08	0.0001
RCC	Pyelonephritis	
1.42±0.22	1.06±0.21	0.0004
RCC	AML	
1.42±0.22	1.06±0.21	0.0001

Figure 1



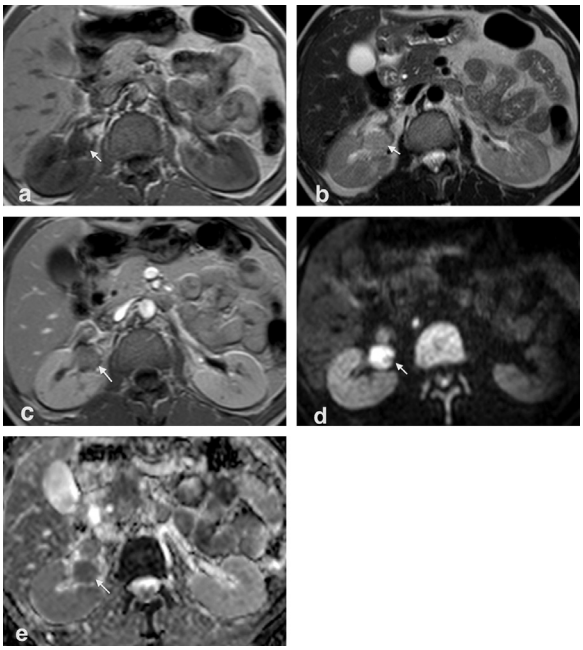
(a–e) A 63-year-old man with clear cell RCC. There is a small left lower pole renal lesion (arrows) showing a low signal on the axial T1-weighted (T1WI) (a), high signal on the axial T2-weighted (b), and homogenous contrast enhancement on the postcontrast axial T1WI (c). Diffusion-weighted imaging with a *b* value of 1000 shows restricted diffusion of the lesion, (d) with an apparent diffusion coefficient value of 0.9×10^{-3} mm^2/s in the corresponding ADC map (e). Note free diffusion of the small right cortical renal cyst.

Figure 2



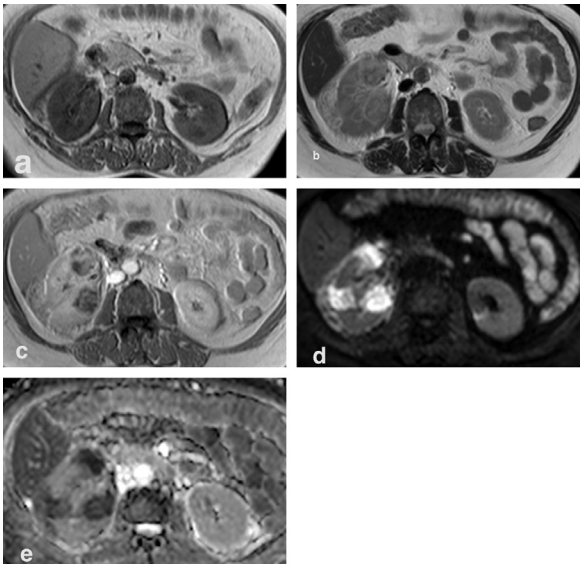
(a–e) A 55-year-old woman with lymphoma. There are multiple bilateral small lesions ranging in size from 1 to 3 cm, eliciting a low signal on the axial T2-weighted (T2WI) (a), and fat-suppression T2WI (b) with faint homogenous enhancement on the postcontrast axial T1-weighted, (c) diffusion-weighted imaging with a *b* value of 1000 shows restricted diffusion of the lesions, (d) their mean apparent diffusion coefficient (ADC) values range from 0.793 to 0.926×10^{-3} mm^2/s on the corresponding ADC map (e). Note enlarged retroperitoneal lymphadenopathy with an ADC value of 0.627.

Figure 3



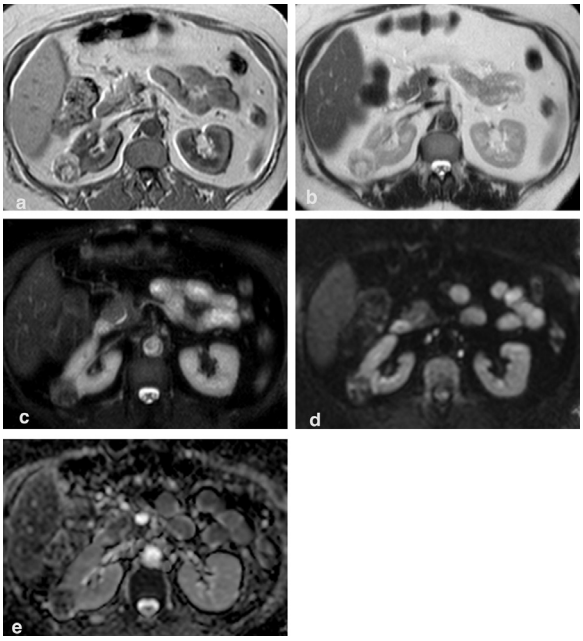
(a–e) A 52-year-old man with TCC. Axial T1-weighted (T1WI) shows a small mass lesion filling the right renal pelvis (arrows) eliciting a low signal on the axial T1WI (a), a high signal on the axial T2-weighted (b), and homogenous contrast enhancement on the postcontrast axial T1WI (c). Diffusion-weighted imaging with a *b* value of 1000 shows restricted diffusion of the lesion (d), with an apparent diffusion coefficient (ADC) value of 1.04×10^{-3} mm^2/s in the corresponding ADC map (e).

Figure 4



(a–e) A 63-year-old woman with right renal pyelonephritis. There are multiple small focal lesions of altered signal in the right kidney eliciting a low signal on the axial T1-weighted (T1WI) (a), a high signal on the axial T2-weighted (T2WI) (b), and heterogeneous enhancement on the postcontrast axial T1WI (c) as well as thickening of Gerota's fascia and the perinephric fat planes. Diffusion-weighted imaging with a *b* value of 1000 shows restricted diffusion of the lesions (d). Their mean apparent diffusion coefficient (ADC) values range from 0.98 to 1.343×10^{-3} mm^2/s in the corresponding ADC map (e).

Figure 5



(a–e) A 61-year-old woman with right renal AML. A small lesion is noted at the right middle renal zone with an exophytic appearance eliciting a mixed signal on the axial T1-weighted (a), axial T2-weighted (b), and drop signal on the T2 spectral presaturation with inversion recovery-weighted image (c). Diffusion-weighted imaging with a *b* value of 800 shows restricted diffusion of the lesion, (d) with an apparent diffusion coefficient (ADC) value of 1.073×10^{-3} mm^2/s in the corresponding ADC map (e).

Discussion

Recent studies have shown that DWI may enable characterization of renal lesions and in differentiating benign from malignant ones [8–13]. However, there are only a few reports investigating the utilization of DWI and ADC value in the differentiation of small solid renal masses [2,14,15].

In this study, we assessed the value of DWI and ADC measurement for the characterization of small solid renal lesions and differentiation between benign and malignant lesions.

The mean ADC value of the normal renal parenchyma in our study was $2.1\pm0.18\times10^{-3}$ mm^2/s, which is within the same range as that found in previous studies, with reported ADC values of $1.85\pm0.12\times10^{-3}$ mm^2/s [2] and $2.19\pm0.17\times10^{-3}$ mm^2/s [15]. However, higher levels were reported in other studies, reaching 3.36 ±0.41 and $2.88\pm0.65\times10^{-3}$ mm^2/s, respectively [12,16].

In addition, the mean ADC values of benign and malignant lesions were significantly lower than those of the normal renal parenchyma. These results are in agreement with a study by Agnello *et al.* [2], who found a lower mean ADC value of the solid renal lesions compared with renal parenchyma (1.22±0.3 vs. 1.85 ±0.12). Similarly, Cova *et al.* [16] reported a lower mean ADC value of the solid renal lesions compared with renal parenchyma (1.55±0.2 vs. 2.19±0.17).

RCC is the most common malignant renal tumor in the literature and in the current study, being encountered more frequently than other malignant lesions such as TCC and lymphoma [12,17]. RCC lesions have variable appearances on DWI because of their different degrees of cellularity and cystic, necrotic, and hemorrhagic components, thus yielding different ADC values [18].

In the current study, all RCC cases showed restricted diffusion, with a mean ADC value of $1.4\pm0.2\times10^{-3}$ mm^2/s. Similarly, TCC lesions showed bright restricted diffusion owing to their high cellularity against the suppressed background of the collecting system and adjacent normal renal parenchyma [19]. The mean ADC value of TCC lesions was 1.26 $\pm0.16\times10^{-3}$ mm^2/s. There was no statistical significance between the mean ADC values of the two groups (P=0.2). This was an agreement with the findings of Sevcenco *et al.* [14]; hence, it is hard to depend on it in distinguishing between the two lesions. Previous studies have also reported higher ADC values of RCC than those of TCC [11,20].

Lymphomatous lesions in the current study showed the lowest ADC values in the malignant category $0.679\pm0.080\times10^{-3}$ mm^2/s, with a statistical significance between the mean ADC value of lymphomatous lesions and that of the RCC lesions (P=0.0001). This was in agreement with the findings of previous studies [21–23] as they reported a range between 0.64 and 0.76×10^{-3} mm^2/s. Visual/qualitative analysis of DWI can aid in the depiction of multiple lesions against a suppressed background signal [21].

Fat-containing AMLs can be identified easily using conventional MRI. Recent studies have been investigating the role of DWI as an interesting sequence in suggesting a benign nature in minimal fat-containing AMLs [2]. Visual evaluation of DWIs in AML is relevant because of the high contrast with the surrounding parenchyma and can be useful in the detection of small renal lesions [24].

This study included nine fat-containing small AML lesions; their mean ADC value was $0.966\pm0.18\times10^{-3}$ mm^2/s, which was significantly lower than that of RCC (P=0.0001). Similar results were reported in previous studies [5,18,25,26]. However, contrasting results were found by Inci *et al.* [17], who reported a higher ADC value of AMLs (1.19±0.36), with no significant difference from RCCs (1.12±0.23). Also, Kilickesmez *et al.* [7] found a higher ADC value of AMLs (1.40±0.21) than for RCC (1.06±0.39).

Pyelonephritis presents as patchy nonmass-like areas of restricted diffusion within the renal parenchyma and should not be mistaken for malignancy; hence, DWI may be useful as it may be used as an additional sequence to differentiate between inflammatory and malignant lesions [27]. Similar to the results of Goyal *et al.* [28], we found statistically significant differences between the ADC value of RCC lesions and that of pyelonephritis (P=0.004).

Diffusion-weighted MRI is extremely useful in patients with impaired renal functions [5] as there is now growing interest in using nonenhancing imaging modalities in the characterization of different renal lesions in these patients [29,30]. In this study, the findings of DWI were particularly useful in the detection and evaluation of lesions in two out of five patients with pyelonephritis who had impaired renal functions and intravenous contrast could not be administered because of the possible risk of contrast-induced nephropathy and nephrogenic systemic fibrosis.

Among all the 30 patients in our study presenting with 50 small renal lesions, overall, there was a considerable overlap between the ADC values of benign and malignant lesions. Moreover, there was no statistically significant difference in the mean values between the two groups (P=0.5). This was an agreement with the results of recent studies [2,14,15].

However, other studies [9,10,17] have reported contrasting results; they reported on the ability of DWI and ADC values to differentiate between benign and malignant lesions. The potential reason for this discrepancy is the different categories of benign lesions in our study as we only included solid lesions such as pyelonephritis and AMLs, which have the lowest ADCs among focal renal lesions, whereas in the other studies, most of the benign lesions were cystic lesions. The addition of simple renal cysts with high ADC values described the discrepancy reported by the previous studies [9,10,17] and the disagreement with our series which is caused by selection bias.

In terms of the technical parameters, ADC measurements are affected by the choice of b values. The use of high b values (>500 s/mm^2) is considered more accurate for true diffusion and results in lower ADC values [20]. In the literature, there is no consensus on the optimal b value at DWI [18,19]; the value of 1000 mm^2/s has been considered to be a reasonable threshold. Zhang *et al.* [31] reported that the main drawbacks of DWI are the lack of standardization, the variability of ADC values because of differences in b values, coil systems, breath-hold versus free breathing techniques, and field strengths used for MRI. The current non uniformity of DWI techniques, together with the presence of interscanner and intrascanner variability in ADC measurement, is limiting the routine use of ADC values [32].

Our study had a few limitations, including the relatively small number of lesions in each group and the fact that not all lesions were diagnosed histopathologically. In addition, DWI has limitations such as poor spatial resolution and anatomic localization with the use of high b values.

Conclusion

DWI is a fast sequence that can be added easily to a routine MRI protocol. DWI is notably valuable in lesion detection and evaluation when gadolinium contrast medium cannot be administered. However, because of the overlap of ADC values between benign and malignant lesions, it cannot be used as a single diagnostic tool and should be concurrently interpreted in conjunction with conventional MRI for optimal characterization of renal lesions.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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