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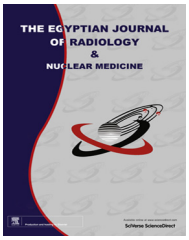

ORIGINAL ARTICLE

Assessment of vascular invasion in pancreatic carcinoma by MDCT

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KEYWORDS

Pancreatic;
Carcinoma;
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Abstract *Background:* Pancreatic cancer is one of the aggressive cancers with poor resectability and survival rates. The relationship to adjacent vessels must be assessed before deciding the choice of treatment.

Aim: Assessment of the MDCT signs of arterial and venous invasion in pancreatic carcinoma.

Subjects and methods: Total of 179 of the major peripancreatic vessels (CA; CHA; SMA; PV; SMV) in 47 patients who underwent surgery for pancreatic cancer after MDCT were assessed at surgery and compared with CT findings. Statistical analysis of the findings was done using Chi square test.

Results: 115 vessels were not invaded at surgery, while the remaining 64 vessels were invaded (22 arteries and 42 veins). There was over all statistically significant difference between arterial and venous invasion regarding stenosis, occlusion, infiltration and circumferential involvement of the vessel wall.

Conclusion: Assessment of vascular invasion is crucial in the evaluation of resectability for pancreatic cancer. MDCT is an accurate diagnostic tool for peripancreatic vascular invasion in cancer pancreas.

1. Introduction

Pancreatic cancer is considered one of the most deadly and aggressive cancers. The resectability and 5-year survival rates for pancreatic cancer are still very poor with survival rates for cancers of the pancreatic body and tail about 10% & that for pancreatic head about 19% (1–4). The complication rates of pancreatic surgery are approximately 40%. It is therefore crucial to correctly identify patients who would most benefit from surgery i.e., those with lesions potentially responsive to curative resection, and reduce as much as possible the number of unnecessary laparotomies (5). In addition to diagnosing and

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staging a pancreatic carcinoma, the relationship of the tumor to major peripancreatic vessels, including celiac artery (CA); common hepatic artery (CHA); superior mesenteric artery (SMA); portal vein (PV); superior mesenteric vein (SMV) must be thoroughly assessed, since their involvement can preclude resection (6). CT is the established method for diagnosing and staging pancreatic carcinoma (7,8). The introduction of MDCT has allowed further refinements in detecting pancreatic adenocarcinoma and in determining unresectability (8–11). Multi-detector row CT (MDCT) scanning of the pancreas enables multiphasic thin collimation scanning, with excellent spatial resolution, especially in the z-plane (9). These volume data sets can be easily manipulated with three-dimensional imaging, potentially providing additional information to conventional axial scans (12).

2. Aim of work

The purpose of our study was to assess the MDCT signs of arterial and venous invasion in pancreatic carcinoma.

3. Patients and methods

Between October 2010 and March 2013, 112 consecutive patients with suspected pancreatic carcinoma underwent biphasic MDCT for pancreatic examination.

3.1. Examination techniques

The following multi-detector CT scanners were used to examine the patients: (TOSHIBA Aquilion 16, Toshiba Medical systems, Japan) for 82 patients, and (Siemens Emotion 16; Siemens, Erlangen, Germany) for 30 patients, 600–800 ml of water or water soluble contrast agent was given orally to patients prior to the study to distend stomach, duodenum & proximal jejunum. Each patient received 100 ml of non-ionic contrast material (iopromide 370 mg/ml; Ultravist; Schering, Berlin, Germany) via intravenous injection at the rate of 4 ml/s. Unenhanced and biphasic, late arterial phase and portal venous phase, enhanced scans were performed. We routinely use bolus tracking, positioning a region of interest on the abdominal aorta at the level of the celiac axis and using an enhancement threshold of 110 HU, late arterial phase (10-s delay from the time of peak aortic enhancement), and a portal venous phase (35-s delay).

The CT examinations were performed in the cranio-caudal direction. The following scanning parameters were used for both 16-channel multi-detector CT scanners: detector configurations of 16×0.75 mm, section thickness of 3.0 mm reconstruction intervals of 1.5 mm for both scanners, table speeds of 17.0 mm per rotation, effective amperage settings of 200 mAs; rotation times of 0.5 s; tube voltage of 120 kVp; and a matrix of 512×512.

3.2. Image analysis and surgical correlation

Pancreatic tumor relation to major peripancreatic vessels, including celiac artery (CA); common hepatic artery (CHA); superior mesenteric artery (SMA); portal vein (PV); and superior mesenteric vein (SMV), was determined preoperatively at consensus reading of axial CT source images combined with post-processed images by two radiologists using the following criteria:

1. Contiguity of tumor with the adjacent vessel was graded A, D based on that suggested by Li et al. (13) and the template provided by Gottlieb et al. (14): Grade A, fat plane or normal pancreatic tissue visible between tumor and vessel; Grade B (*Abutment*) and Grade C (*Encasement*), tumor surrounding of less than and more than 50% of the vessel circumference respectively; Grade D, arterial embedment in tumor or venous occlusion.
2. Detailed vascular anatomic deformation: vessel stenosis presented a semi-circular or concentric smaller contour of the vessel. A straight contour on one side was regarded as flattened, not as stenosis. Vessel wall infiltration presented as irregular and indented shape at the vascular margin abutting tumor.

At surgery, 179 out of 235 vessels were properly assessed, the remaining 56 vessels were inadequately assessed either due to deeply seated vessels or matting with adjacent structures. The surgical criterion of tumor ingrowth into the vessels was that the vessel could be observed, or found by palpation to be infiltrated or occluded at surgery. Easy separation of an adherent vessel from its surrounding tissue during surgery was a clinical sign of perivascular adhesion due to inflammatory or fibrotic reaction rather than tumor invasion.

An informed consent was taken from all patients before performing the MDCT and surgery after explanation of the procedures and their benefits or potential hazards. All data collected were coded to insure patient privacy.

3.3. Statistical analysis

Chi-square tests were performed on the difference between the number of affected arteries and veins, and on the MDCT signs: (a) vessels showing stenosis or occlusion; (b) vessels showing wall irregularity; (c) tumor surrounding more than 50% of the vessel circumference; to check for any significant difference between the invaded arteries and veins. A P value of < 0.05

Table 1 Grade A, C: the grade of contiguity of tumor with the adjacent (115) non-invaded vessels (SMA, superior mesenteric artery; CA, celiac artery; CHA, common hepatic artery; PV, portal vein; SMV, superior mesenteric vein).

	SMA	CA	CHA	PV	SMV	Total
Grade A	15	20	22	27	16	100
Grade B < 50% Abutment	3	1		2	3	9
Grade C > 50% Encasement	1		1		4	6
Total	19	21	23	29	23	115

Table 2 The differences in the frequency of arterial and venous invasion on MDCT.

CT signs	Artery				Vein			Chi^2	*p*-Value
	SMA	CA	CHA	Total	SMV	PV	Total		
Vessel stenosis or occlusion	4/13	2/4	2/5	8/22	16/25	11/17	27/42	4.542	0.033
Vessel wall irregularity	7/13	2/4	2/5	11/22	18/22*	11/15*	29/37	5.09	0.024
Tumor contiguity > 50% of vessel circumference	12/13	4/4	5/5	21/22	12/22*	9/15*	21/37	10.073	0.002

* Five veins (3 SMVs, 2 PVs) totally occluded by tumors were not included.

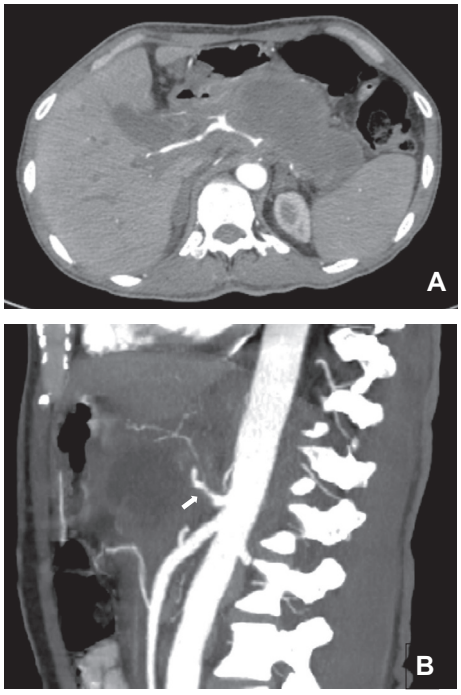

Fig. 1 (A) Axial CT scan of the abdomen at the level of the celiac artery in a patient with pancreatic body adenocarcinoma in the arterial phase showing encasement of the celiac & common hepatic arteries by the mass causing stenosis of its lumen. (B) Sagittal thick slab MPR of the abdomen at the level of the celiac & superior mesenteric arteries in the same patient showing encasement of the celiac artery by the mass appearing as irregularity and narrowing of its lumen (arrow).

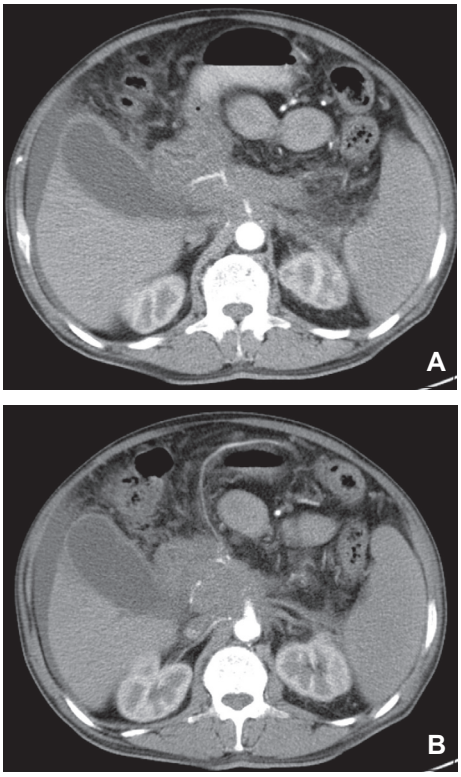

Fig. 2 (A) Axial CT scan of the abdomen at the level of the celiac artery in a patient with pancreatic body adenocarcinoma in the arterial phase showing encasement of the celiac & common hepatic arteries and its branches by the mass causing marked narrowing and irregularity of their outlines. (B) Axial CT scan of the abdomen at the level of the SMA artery in the same patient with pancreatic body adenocarcinoma in the arterial phase showing encasement of the SMA artery and its branches by the mass causing near total occlusion of their lumens.

was considered statistically significance. Sensitivity and specificity of the resectability based on the CT and operative findings were calculated. Statistical software used was Minitab 16 (Minitab Inc., USA).

4. Results

CT showed pancreatic masses in 82 patients and pancreatic carcinoma was pathologically confirmed by biopsy or fine-needle aspiration. MDCT images of the 82 patients were all prospectively evaluated for resectability: including vascular invasion and the presence of metastatic disease. Forty-seven patients were pre-operatively judged to be resectable or requiring surgical bypass due to jaundice. The remaining 35 patients deemed irresectable from the beginning and received chemotherapy or radiotherapy. The 47 candidates for surgery were 32 males and 15 females, with their age range between 45 and 82 years old, mean 63.5 years. Fifteen patients underwent pancreaticoduodenectomy, cases judged to be resectable, and 32 patients underwent palliative surgery. The time interval between MDCT examination and surgery was less than 2 weeks.

In 25 patients of the 47 who underwent surgery, their tumors were located in the pancreatic head or uncinate process and in the other 22 their tumors were located in the pancreatic body or tail.

Thirteen patients out of the 15 with who underwent pancreaticoduodenectomy (resectable tumors), were correctly diagnosed by MDCT preoperatively. Two were incorrectly judged to be irresectable because MDCT had shown tumor ingrowth into the SMA ($n = 1$) & CHA ($n = 1$).

Among the 32 patients, who received by-pass palliative surgery or surgical exploration, 6 patients were incorrectly diagnosed as having resectable tumors, due to missing vessels invasion in 4 cases and missed hepatic metastases in 2. Based on the previous findings the sensitivity and specificity for tumor resectability by MDCT are 84.2% and 88.2% respectively.

Out of the 179 observed vessels (97 arteries & 82 veins), 115 vessels were found not to be invaded at surgery and 64 were invaded (22 arteries & 42 veins).There was a statistically significant difference between the number of invaded arteries and veins, $Chi^2 = 15.756$ and $p < 0.0001$.

MDCT findings in non-invaded 115 vessels as regards their relation to the tumor after surgical confirmation are shown in Table 1:

1. Grade A of contiguity of tumor with the adjacent vessel (fat plane or normal pancreatic tissue preserved) ($n = 100$, 15 SMAs, 20 CAs, 22 CHAs, 16 SMVs and 27 PVs).
2. Grade B (Abutment) of contiguity of tumor with the adjacent vessel ($< 180°$) ($n = 9$, 3 SMAs, 1 CA, 3 SMVs, 2 PVs).
3. Grade C (Encasement) of contiguity of tumor with the adjacent vessels ($> 180°$) ($n = 6$, 4 SMVs, 1 SMA, 1 CHA).

MDCT signs in the 64 vessels with proven tumor invasion, with statistical analysis of the difference in the frequency of findings between the arteries and veins are shown in Table 2.

Eight of the 22 of the invaded arteries, representing 36%, appeared stenosed and 27 of the 42 invaded veins, representing 64%, appeared as stenosed or occluded (Fig. 1a and b). Seven veins (4 SMVs, 3 PVs), which were surrounded less than 50% of the vessel circumference by tumor, also appeared stenosed, the difference between the stenosis of arteries & veins was statistically significant with $p = 0.033$.

Twenty-nine of the 37 invaded veins, representing 78% after exclusion of 5 occluded veins, appeared infiltrated with an irregular wall. Three of the infiltrated veins (2 SMVs, 1 PV) showing irregular walls, were surrounded by less than 50% of the vessel circumference and were not stenosed (Fig. 4a–c).

Eleven of 22 invaded arteries, representing 50%, appeared infiltrated less often than the invaded veins, after exclusion of 5 occluded veins, there was a statistically significant difference between the frequency of infiltration of the arteries and veins with $p = 0.024$. (Figs. 2a and b, 3a–c).

Twenty-one of 37 veins with invasion, representing 57%, with exclusion of 5 occluded veins were surrounded by more than 50% of the vessel circumference by tumor.

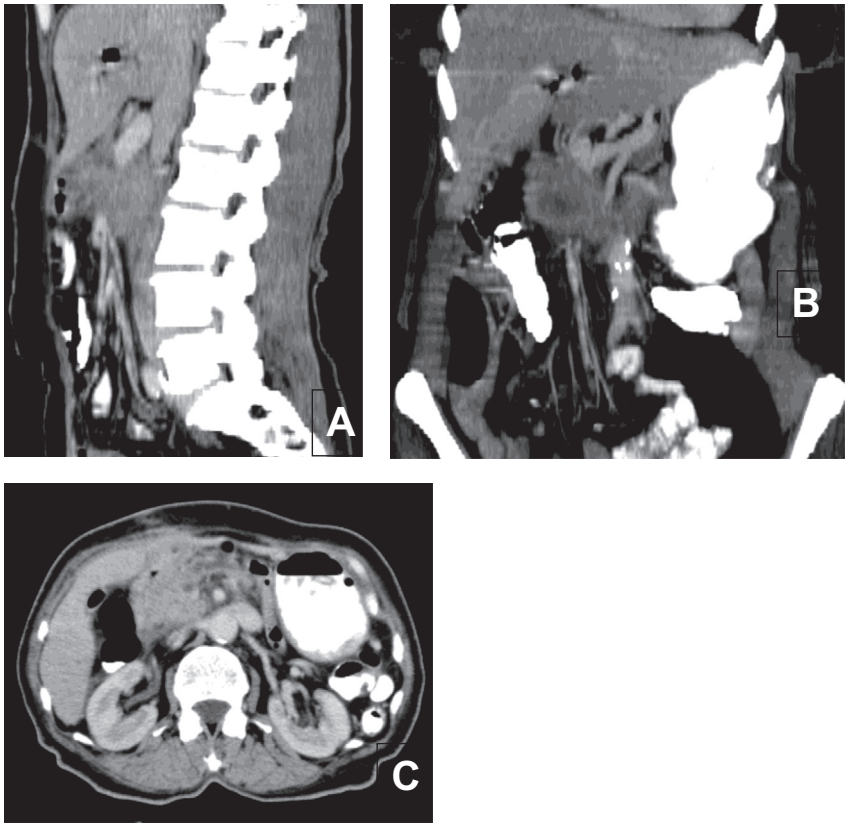

Fig. 3 (A) Sagittal thick slab MPR image of a patient with pancreatic adenocarcinoma in the portal venous phase showing encasement of SMV causing near total occlusion of its lumen by the mass. (B) Coronal MPR image of the same patient with pancreatic adenocarcinoma in the portal venous phase showing the mass and its relation to the SMV with loss of its proximal opacification denoting occlusion. (C) Axial image of the same patient with pancreatic adenocarcinoma in the portal venous phase showing the mass and its relation to the SMV which is hardly identified, note the clear planes around the SMA.

Twenty-one of 22 invaded arteries, representing 95%, were surrounded by more than 50% of the vessel circumference by tumor or were embedded in tumor.

Statistical analysis showed a significant difference between invaded arteries and veins utilizing circumferential involvement of more than 50% of the vessel circumference by tumor with $p = 0.002$.

As regards other MDCT appearances of arterial and venous invasion, 2 of 25 invaded SMVs, representing 8%, were diagnosed correctly as they had a ''teardrop'' appearance in the axial images. When invaded veins were highly stenosed or occluded, 17% (7/42), multiple venous collaterals were seen.

In 4 cases out of 22 showing invaded arteries, representing 18%, the arteries appeared deformed and seemed to be stretched or stiffened in three dimension reconstruction images, such as Volume rendering (VR) (Fig. 1b).

5. Discussion

Cancer pancreas is one of the most aggressive malignant tumors and represents the fourth cause of death from cancer. It is usually associated with poor prognosis, this is likely due to the deep location of the pancreas in the abdomen with its close relation to major vessels and the tendency of the tumor for early local and distant spread (15).

According to Egorov et al. (16), the vascular involvement in patients with pancreatic carcinoma ranges between 21% and 64%.

Recently MDCT has become the most important and reliable imaging modality in assessing patients with pancreatic adenocarcinoma. It plays an important role in diagnosis of pancreatic malignancy regarding the localization, size, dissemination and staging of the tumors (17).

Many criteria were postulated for unresectability of the pancreatic cancer, however assessment of vascular invasion is considered one of the most important parameters for resectability in the absence of metastatic disease which precludes resection (18).

Our findings were in agreement with Shokry et al. (19) who stated that the CT signs of arterial and venous involvement in pancreatic cancer are different, this is likely due to more thin and less flexible walls of the veins, so when the vein is involved it tends to be irregular and narrowed. In the same way, venous occlusion is more common than arterial occlusion.

In our study, we adopted the method of evaluation of the signs of arterial and venous invasion separately, suggested by Li et al. (13), and in agreement with their findings we found that it improves the accuracy of reporting the degree of vascular invasion.

In this study, three major arteries, namely the celiac artery (CA), superior mesenteric artery (SMA) and common hepatic artery (CHA) were carefully analyzed as their infiltration is an important criterion for unresectability. We agreed with Buchs et al. (18) that the superior mesenteric vessels are the most frequently involved vessels in pancreatic cancer due to their anatomical location closely adjacent to the pancreas. Our results showed that encasement of the SMA was seen in 12 patients,

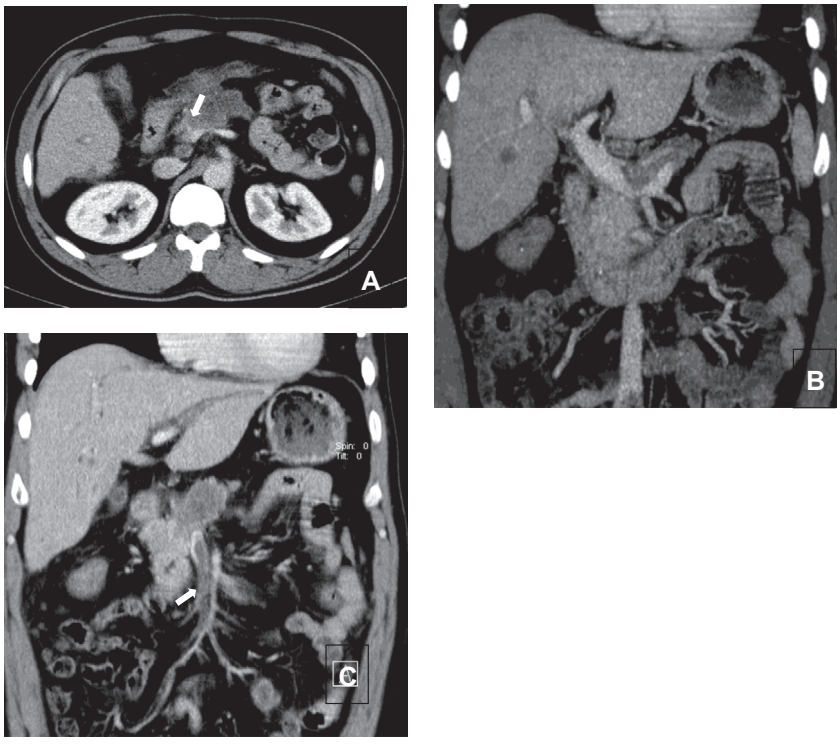

Fig. 4 (A) Axial image of a patient with pancreatic adenocarcinoma in the portal venous phase showing the mass invading the PV at its confluence (arrow), note the clear planes around the CA. (B) Coronal MPR image of the same patient with pancreatic adenocarcinoma in the portal venous phase showing the relation of the mass to the PV with filling defect within its lumen representing tumor thrombus. The patient showed a deposit in its right lobe at segments VIII and V. (C) Coronal MPR image of the same patient with pancreatic adenocarcinoma in the portal venous phase showing extension of thrombus along the SMV (arrow).

while encasement of the CA was seen in 4 patients and CHA in 5 patients. Our findings are in agreement with those of Brugel et al. (20) and Vargas et al. (21) that with cross-sectional imaging, the relationship between the tumor and the superior mesenteric vessels can be assessed more accurately. We also agreed with them in that combining axial source data with VR and curved MPR images is the optimal method for evaluation of unresectability.

On other hand, our statistics revealed that venous stenosis and occlusion are more common than that of the adjacent arteries. Twenty-seven of the 42 invaded veins, representing 64%, appeared as stenosed or occluded, in comparison to 8 out of the 22 invaded arteries representing 36% showed significant stenosis. However isolated Venous involvement is not considered as contraindication for surgery by most of pancreatic surgeons as mentioned by Li et al. (13). This is because venous resections and reconstructions are increasingly performed and the technique becomes more feasible and reliable.

In the same way the arterial wall is more resistive to neoplastic infiltration than the venous wall, this is again due to its more thickness and flexibility. In our study vascular infiltration was seen more in involved veins (78%) than in involved arteries (50%). Similar results were mentioned by Shokry et al. (19).

The teardrop mesenteric vein sign was described by Li et al. (22) as a specific sign of tumor involvement of the SMV. It refers to a focally tethered SMV assuming a shape of a teardrop. This sign presumably results from either direct tumor infiltration or peritumoral fibrosis adherent to the vessel that retracts or tethers the vessel, changing its normal round shape. It was considered as sign of unresectability. In our study, there were two invaded SMVs confirmed by surgical exploration and exhibiting the teardrop sign on axial images.

In our study, two arteries (one SMA, one CHA) were found not to be invaded at surgical exploration, although they were surrounded by more than 50% of the vessel circumference, but their caliber remained unchanged and the walls were regular.

Since pancreatic carcinoma may be accompanied by focal tissue fibrosis, the invaded arteries may appear stretched as reported by Horton et al. (12). In our study, four stretched arteries were appreciated on three-dimensional reconstruction MDCT angiography (MDCTA) images.

The sensitivity and specificity of tumor resectability based on MDCT findings in this study were 84.2% and 88.2% respectively which are in agreement with those reported by Morgan et al. (23)

A major limitation of our study is that our gold standard is the surgical palpation, because irresectable tumors could not be histologically assessed.

6. Conclusion

In conclusion, the frequency of venous invasion by pancreatic tumors is significantly higher than arteries, and despite the similarity in the MDCT signs of vascular invasion between arteries and veins they are seen significantly more in veins than arteries. It is important to pay attention to these differences in order to improve the accuracy of diagnosing vascular invasion and pancreatic resectability.

Conflict of interest

None.

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