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Editorial Board Member of *World Journal of Clinical Cases*, Md Moshiur Rahman, MBBS, Assistant Professor, Department of Neurosurgery, Holy Family Red Crescent Medical College Hospital, Dhaka 1000, Bangladesh. dr.tutul@yahoo.com

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ORIGINAL ARTICLE

Observational Study

Prior abdominal surgery as a potential risk factor for colonic diverticulosis or diverticulitis

Eran Ariam, Vered Richter, Anton Bermont, Yael Sandler, Daniel L Cohen, Haim Shirin

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Eran Ariam, Department of Gastroenterology, Kaplan Medical Center, Rehovot 76100, Israel

Vered Richter, Anton Bermont, Daniel L Cohen, Haim Shirin, The Gonczarowski Family Institute of Gastroenterology and Liver Diseases, Shamir Medical Center, Zerifin 70300, Israel and the Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

Yael Sandler, Department of Surgery Division, Shamir Medical Center, Zerifin 70300, Israel

Corresponding author: Daniel L Cohen, MD, Gastroenterologist, The Gonczarowski Family Institute of Gastroenterology and Liver Diseases, Shamir Medical Center, Zerifin 70300, Israel. docdannycohen@yahoo.com

Abstract

BACKGROUND

Abnormal colonic pressure profiles have been associated with an increased risk of colonic diverticulosis. A surgical history is a known risk factor for abdominal adhesions and these may lead to increased intraluminal colonic pressure.

AIM

To assess whether previous abdominal surgery is associated with colonic diverticulosis or diverticulitis.

METHODS

We analyzed data from a study of patients undergoing colonoscopy for different indications from 2020 through 2021. Patients completed a structured questionnaire concerning previous abdominal surgeries, dietary and lifestyle exposures including smoking, alcohol use and co-morbidities.

RESULTS

Three hundred and fifty-nine patients were included in the study. The mean age was 67.6 and 46% were females. Diabetes mellitus, hypertension, ischemic heart disease, chronic obstructive pulmonary disease, chronic renal failure, and body mass index were similar in the diverticulosis and control groups. The overall prevalence of colonic diverticulosis was 25% (91/359) and 48% of the patients had previous abdominal surgery. As expected, the prevalence of diverticulosis increased with age. There was no difference in the rate of previous abdominal surgery between patients with or without diverticulosis (49% *vs* 47%, $P = 0.78$). In regards to specific surgeries, inguinal hernia repair was significantly associated

with diverticulosis (52% *vs* 20%, P = 0.001), but not diverticulitis. In contrast, appendectomy was not associated with diverticulosis (6% *vs* 14%, P = 0.048).

CONCLUSION

These findings suggest that post-operative abdominal adhesions inducing high colonic intraluminal pressures do not appear to be the mechanism for diverticula formation. Rather, inguinal hernia and diverticulosis may share similar connective tissue pathologies with no causative relationship between them.

Key Words: Diverticulosis; Diverticulitis; General surgery; Adhesions; Risk factors; Abdomen

Core Tip: Prior abdominal surgery is a risk factor for the development of adhesions. The presence of adhesions may lead to increased intraluminal colonic pressures and, therefore, the formation of diverticula. We sought to evaluate if there was a correlation between a history of abdominal surgery and colonic diverticulosis or diverticulitis. However, we found that a history of prior surgery was not associated with either diverticulosis or diverticulitis. Of the specific surgeries, only inguinal hernia repair was associated with diverticulosis, but this appears to be due to other mechanisms and not adhesions.

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INTRODUCTION

Diverticulosis coli is one of the leading causes of morbidity in Western countries. Despite its high prevalence, the pathogenesis of diverticulosis remains poorly understood. Multiple risk factors including gender, genetics, neuromuscular function abnormalities, mucosal inflammation, diet and obesity have been identified[1]. Abnormal colonic pressure profiles and high intraluminal pressures are also postulated to contribute to the formation of sigmoid colon diverticulosis[2]. It has been hypothesized that in colonic diverticular disease, higher intraluminal pressures in the affected segments may contribute to the production of pulsion diverticula[3]. In addition, colonic motility and neuromuscular activity may lead to uncoordinated contractions and high pressure, producing diverticulosis[4-7]. However, a systemic review of colonic manometry studies did not show a significant difference in the mean amplitude or percentage of activity among patients with or without diverticulosis, suggesting that the high pressures in a colonic segment may not be responsible for the diverticular disease[2].

Adhesions are quite common after abdominal surgery with significant morbidity. The overall burden of readmissions associated with adhesions remains high. Krielen *et al*[8] recently studied the impact of laparoscopic *vs* open abdominal/pelvic surgery on adhesion-related hospital readmissions in a population-based cohort. Of the 72270 patients who had surgery, 2527 patients (3.5%) were readmitted within 5 years of surgery for disorders directly related to adhesions, 12,687 (17.6%) for disorders possibly related to adhesions, and 9436 (13.1%) for operations potentially complicated by adhesions. Laparoscopic surgery may reduce the incidence of these adhesion-related readmissions. Moreover, a surgical history, particularly gastrectomy and hysterectomy, were significant independent factors associated with colonoscopy incompleteness[9].

We hypothesized that adhesions due to prior abdominal surgery may alter intracolonic pressure and may be a risk factor for the development of colonic diverticulosis. Our objective was to examine the correlation between previous abdominal surgery and diverticulosis. Because of the current interest in the etiology of diverticulitis, we also compared the effect of abdominal surgery on the incidence of acute diverticulitis.

MATERIALS AND METHODS

The study recruited patients 18 years of age and older presenting for a colonoscopy in the author's medical center between 2020 and 2021. The study was approved by the Institutional Review Board (Approval No. 0107-20-ASF) and all subjects provided informed consent.

All colonoscopes used were high-definition endoscopes (Pentax EC-3890i, Pentax, Tokyo, Japan). Conscious sedation was used (mostly midazolam, fentanyl, propofol, or a combination thereof, according to the physician's preference). The study excluded any patient with: (1) Inadequate preparation (Boston Bowel Preparation Quality Scale < 6); (2) previous colonic resection based on history and colonoscopy; or (3) previous colon cancer.

Questionnaire interviews were conducted prior to the colonoscopy by the physicians participating in the study, although for some of the patients, the questionnaire was completed during a phone interview. The questionnaire included demographic information, medical information, history of surgeries, and whether there was a known history of diverticulosis. Dietary and lifestyle exposures including smoking (none, current or past) and alcohol use (none, more or less than 3 times a week) were ascertained. Participants were asked to estimate consumption of red meat during the year prior to colonoscopy (none, more or less than 3 times a week). Physical activity was counted as any aerobic exercise (none, more or less than 3 times a week). Additional data was collected from the colonoscopy report such as the indication for the examination, presence of diverticulosis, and any additional benign or malignant lesions.

The primary end point was whether there was a significant correlation between prior abdominal surgery and the development of diverticulosis. For patients that were diagnosed with diverticulosis with previous surgery, we searched for past colonoscopy or computed tomography (CT) scan reports to identify the first time they were diagnosed with diverticulosis. When the date of the surgery came after the first diagnosis of diverticulosis, this surgery was not included in the analysis.

Secondary endpoints included an analysis evaluating for the presence of known risk factors for colonic diverticulosis in our study. We also conducted an age- and sex-matched study to check additional comparison between patients that were hospitalized for diverticulitis in our medical center and patients with diverticulosis from the primary study who had not had an episode of diverticulitis. Acute diverticulitis was diagnosed by clinical criteria, leukocytosis, and characteristic CT findings of colonic wall thickening (wall thickness > 3 mm on the short axis of the lumen) and pericolic fat stranding.

Informed consent was obtained from all participants. The study was approved by the author's medical center ethical committee. The work has been reported in line with the STROCSS criteria[10].

Colonoscopy and assessment of diverticulosis

All colonoscopies were performed by experienced attending gastroenterologists. All of the colonoscopies were complete to the cecum. The bowel preparation was graded according to the Boston Bowel Preparation Quality Scale[11]. Endoscopists were instructed to carefully examine the colon for diverticula. The presence of at least one diverticula detected by endoscopy was enough to be considered as diverticulosis.

Statistical analysis

Categorical variables were described as frequency and percentage. Continuous variables were evaluated for normal distribution using histogram and since they were skewed they were reported as median and interquartile rang. Chi-square test and Fisher's exact test were used to compare categorical variables and Mann-Whitney test was applied to compare continuous variables. Patients with and without diverticulitis were matched according to age (+/- 2 years) and sex. The matched groups were compared using McNemar test, paired samples T test and Wilcoxon signed ranks test. Statistical analysis was performed with SPSS statistical software (IBM SPSS Statistics for Windows, version 25, 2017; IBM Corp., Armonk, NY, United States).

RESULTS

From a total of 450 patients undergoing colonoscopy, we excluded 46 patients because of incomplete endoscopy and another 45 patients because they had undergone a partial colectomy. This left 359 eligible patients included in the study. The mean age was 67.6 and 46% were females. Demographic and epidemiologic characteristics of the patients are presented in Table 1.

Diabetes mellitus, hypertension, ischemic heart disease, chronic obstructive pulmonary disease, chronic renal failure and body mass index (BMI) were all similar between the diverticulosis and control groups. The clinical indications for colonoscopy and the endoscopic findings were typical for a gastroenterology unit (Table 2).

The overall prevalence of colon diverticulosis was 25% (91/359) and 48% of the patients had a prior abdominal operation. As expected, the prevalence of diverticulosis increased with age (66.29 *vs* 71.76, $P < 0.001$; Table 1). We did not find any association between diverticulosis and reported environmental, behavioral or medical variables such as alcohol, smoking, education level, red meat consumption, exercise frequency, adenomatous polyps, and atherosclerotic disease (Table 1).

There was no difference in the rates of prior abdominal surgery between patients with or without diverticulosis. However, with regard to specific surgeries, inguinal hernia repair was found to be significantly associated with diverticulosis (6% *vs* 17%, $P = 0.002$; Table 3), but not diverticulitis. In contrast, appendectomy was found to have a protective effect for diverticulosis (6% *vs* 14%, $P = 0.048$).

Further analyses were performed amongst the subjects with diverticulosis by matching those that had a history of diverticulitis to ones without. These analyses showed no significant differences in demographic or medical conditions between the groups (Table 4), nor differences in the rates of prior abdominal surgery (Table 5).

DISCUSSION

Our study is the first to investigate whether abdominal surgery, presumably by means of adhesion-related increased colonic intraluminal pressure, may contribute to the development of diverticulosis or diverticulitis.

Table 1 Demographic and epidemiologic characteristics of the patients with and without diverticulosis

Characteristics	Without diverticulitis, *n* = 268	With diverticulitis, *n* = 91	*P* value
Mean age	66.29	71.76	< 0.001
Male sex as %	53.7	52.7	0.870
Mean BMI	28.4	27.6	0.710
Origin			0.420
Israel	103 (38)	32 (35)	
South Europe	93 (34)	27 (29)	
Ethiopia	3 (1)	3 (3)	
Sefaradi	58 (21)	24 (26)	
Ashkenazi	11 (4)	5 (5)	
Residence			
Urban	254 (94)	85 (93)	0.620
Rural	14 (5)	6 (6)	
Marital status			
Married	179 (66)	23 (69)	0.660
Not married	89 (34)	28 (31)	
Smoking			
Never	123 (46)	52 (57)	0.190
Previous	90 (33)	24 (26)	
Current	54 (20)	15 (16)	
Alcohol			
No drinking	196 (73)	67 (73)	0.920
Drinking	72 (27)	24 (27)	
Red meat			
None	23 (8)	4 (4)	0.065
< 3 times a week	213 (80)	83 (91)	
> 3 times a week	28 (10)	4 (4)	
Exercise			
None	130 (48)	54 (59)	0.200
< 3 times a week	80 (30)	22 (24)	
> 3 times a week	58 (21)	15 (16)	
Education			
< 12 yr	63 (23)	26 (28)	0.620
12 yr	84 (31)	27 (29)	
> 12 yr	121 (45)	38 (41)	
Chronic disease			
Diabetes	98 (36)	31 (34)	0.660
IHD	57 (21)	23 (25)	0.420
HTN	156 (58)	62 (68)	0.094
COPD	22 (8)	7 (7)	0.870
CRF	17 (6)	4 (4)	0.490
Hypothyroidism	33 (12)	8 (8)	0.360

Vitamin D deficiency	103 (38)	31 (34)	0.450
Medications			
Aspirin	97 (36)	34 (37)	0.840
NSAIDs	1 (0.4)	1 (1)	> 0.990
GC	2 (0.7)	4 (4)	0.038
Opiates	9 (3)	3 (3)	> 0.990
PPI	105 (39)	34 (37)	0.750

Data are *n* (%). BMI: Body mass index; COPD: Chronic obstructive pulmonary disease; CRF: Chronic renal failure; GC: Glucocorticoids; HTN: Hypertension; IHD: Ischemic heart disease; NSAIDS: Non-steroidal anti-inflammatory drugs; PPI: Proton pump inhibitors.

Table 2 Clinical indication for colonoscopy and endoscopic findings

Features	Without diverticulitis, *n* = 268	With diverticulitis, *n* = 91	*P* value
Indication of colonoscopy			0.55
Screening	49 (18)	10 (11)	
Abdominal pain	22 (8)	10 (11)	
Anemia	40 (15)	18 (19)	
Rectal bleeding	24 (9)	9 (10)	
Positive FOBT	17 (6)	9 (10)	
Diarrhea	20 (7.5)	5 (5)	
Constipation	10 (3)	5 (5)	
History of polyps	61 (22)	16 (17)	
Other	24 (9)	9 (10)	
Polyps			0.10
None	177 (66)	52 (58)	
Hyperplastic	12 (4)	1 (1)	
Adenoma	69 (26)	33 (37)	
Malignant	6 (2)	1 (1)	
Hyperplastic + adenoma	2 (0)	2 (2)	

Data are *n* (%). FOBT: Fecal occult blood test.

There is a lack of data in the literature on the relationship between post-operative adhesions and its potential effect on the colon. For example, it is unclear if adhesions would lead to increased colonic intraluminal pressures, as this has been postulated to play a role in diverticular formation[3]. Further, since post-operative adhesions may not occur in the same location as diverticulosis, it is unclear if adhesions in one segment of the intestines could affect the intraluminal pressures or motility of an adjacent segment. Given these areas of uncertainty, we sought to clarify the relationship between the most significant predictor of abdominal adhesions (prior abdominal surgery) and the presence of diverticulosis, without paying attention to the specific location of the surgery or diverticulosis.

Our results indicate that only the repair of inguinal hernias is significantly associated with diverticulosis. This is consistent with previous reports which also showed a significant association between abdominal wall hernia and diverticulosis[12].

However, the correlation between hernia repair surgery and diverticulosis does not appear to be mediated *via* adhesions for several reasons. Firstly, small bowel obstruction (SBO) is a common surgical complication due to adhesions [13,14], but SBO is uncommon after laparoscopic inguinal hernia repair[15]. Additionally, we would have expected increased rates of diverticulosis after major abdominal surgeries, which are more likely to lead to adhesions than hernia repairs, but we did not find this.

Indeed, other studies suggested that connective tissue alterations play a role in the formation of diverticulosis and abdominal wall hernia[16,17]. A large study from Denmark that included 13855 patients found a significant association between inguinal and umbilical hernias and the development of diverticulosis[18]. Perez *et al*[18] published much higher

Table 3 Association between previous surgery and diverticulosis

Feature	Without diverticulitis, *n* = 268	With diverticulitis, *n* = 91	*P* value
Any surgery	128 (47)	47 (49)	0.780
Ventral hernia	19 (7)	9 (9)	0.380
Inguinal hernia	18 (6)	16 (17)	0.002
Cholecystectomy	23 (8)	10 (11)	0.490
Gastric surgery	9 (3)	5 (5)	0.530
Appendectomy	39 (14)	6 (6)	0.048
Small bowel	6 (2)	0 (0)	0.340
Cesarean section	26 (9)	4 (4)	0.110
Gynecological	26 (9)	6 (6)	0.360
Urologic	12 (4)	6 (6)	0.410
Other	4 (1)	1 (1)	> 0.990

Data are *n* (%).

rates of incisional hernia in patients undergoing elective colectomy for diverticulitis compared to those for colon carcinoma resection. Finally, two independent genome-wide association studies have linked diverticulosis to connective tissue formation genes associated with abdominal wall hernias[19,20]. These data suggest that both pathologies share mechanisms of connective tissue alterations and probably develop simultaneously, and therefore do not support inguinal hernia as a causative risk factor for diverticulosis.

In our study, we also found that patients who had a previous appendectomy were less likely to have diverticulosis. This may be related to the theory that the development of diverticular disease is related to alterations in the gut microbiome[21,22]. The appendix is believed to be a reservoir of bacteria that prevent dysbiosis within the colon. The resection of the appendix may cause a change in the bacterial diversity of the gut microbiome which may lead to less diverticula formation[23]. However, our results are in contrast to a recent study which showed that appendectomy was a risk factor for diverticular disease[24]. In that study, although appendectomy was most strongly associated with an increased risk of diverticular disease within 1 year, the association was still present more than 20 years after appendectomy. Moreover, patients with diverticulitis had 2.8 times higher odds of previous appendectomy than the control group suggesting that appendicitis and diverticulitis share similar risk factors and potentially a common pathological link[25].

Our findings that older age and glucocorticoid usage are significantly associated with diverticulosis is consistent with previous studies. Higher consumption of red meat also showed a trend toward diverticulosis. However, we did not find a significant relationship between diverticulosis and other known risk factors such as male sex, smoking, alcohol consumption[26], BMI, medications such as non-steroidal anti-inflammatory drugs and opiates, decreased physical activity[27], hypothyroidism, diabetes mellitus, and atherosclerotic disease[28]. This may be explained by differences in demographic characteristics, the size of the study population, and that other studies only included patients undergoing screening colonoscopy.

Finally, we also compared the known risk factors, including prior surgeries, by matching patients with asymptomatic diverticulosis to those who were hospitalized with an episode of acute diverticulitis. No differences were found between those two groups.

Our study has several limitations. It includes a relatively small number of patients, especially when compared to some population-based studies[12,24]. Due to this, there were only a handful of patients that had certain types of surgery, limiting our ability to perform more advanced statistical analyses. Secondly, the study included patients that underwent colonoscopy in a tertiary-referral hospital Gastroenterology department which might lead to selection bias of patients with more comorbidities compared to the general population. Lastly, we used questionnaires to collect patient's data that might lead to recall bias of patient's surgical history; further surgical details, such as whether the surgery was open *vs* laparoscopic or whether mesh was used, were not obtained.

CONCLUSION

In conclusion, while a prior inguinal hernia repair was significantly associated with the presence of colonic diverticulosis, a history of any prior abdominal surgery was not. These findings suggest that post-operative abdominal adhesions inducing high colonic intraluminal pressures do not appear to be the mechanism for diverticula formation. Rather, inguinal hernia and diverticulosis may share similar connective tissue pathologies with no causative relationship between them.

Table 4 Matching between patients with and without diverticulitis

Characteristics	Without diverticulitis, *n* = 59	With diverticulitis, *n* = 59	*P* value
Mean age	67	67	0.820
Male sex as %	57	57	
Mean BMI	28	26	0.150
Origin			0.470
Israel	24 (47)	31 (52)	
South Europe	19 (32)	12 (20)	
Ethiopia	2 (3.4)	1 (1.7)	
Sefaradi	12 (20)	11 (18)	
Ashkenazi	2 (3)	4 (7)	
Residence			0.620
Urban	56 (94)	58 (98)	
Rural	3 (5)	1 (1)	
Marital status			0.052
Married	36 (61)	46 (78)	
Not married	23 (39)	13 (22)	
Smoking			0.300
Never	32 (54)	23 (39)	
Previous	15 (25)	25 (42)	
Current	12 (20)	11 (18)	
Alcohol			0.390
No drinking	80	83	
Drinking	20	17	
Red meat			0.280
None	1 (1.7)	5 (8)	
< 3 times a week	54 (91)	48 (81)	
> 3 times a week	4 (7)	6 (10)	
Exercise			0.160
None	37 (62)	27 (45)	
< 3 times a week	13 (22)	17 (29)	
> 3 times a week	9 (15)	15 (25)	
Education			0.820
Less than 12 yr	20 (56)	16 (44)	
12 yr	18 (30)	18 (30)	
More than 12 yr	21 (35)	24 (41)	
Chronic disease			
Diabetes	19 (32)	13 (22)	0.210
IHD	9 (15)	8 (13)	> 0.990
HTN	34 (58)	26 (44)	0.210
COPD	7 (11)	2 (3)	0.180
CRF	0 (0)	3 (5)	> 0.990
Hypothyroidism	6 (10)	6 (10)	> 0.990

Vitamin D def.	20 (34)	19 (32)	> 0.990
Medications			
Aspirin	19 (32)	17 (28)	0.830
NSAIDs	1 (1.7)	1 (1.7)	> 0.990
GC	3 (5)	0 (0)	> 0.990
Opiates	2 (3)	0 (0)	> 0.990
PPI	20 (34)	16 (27)	0.540

Data are *n* (%). BMI: Body mass index; COPD: Chronic obstructive pulmonary disease; CRF: Chronic renal failure; GC: Glucocorticoids; HTN: Hypertension; IHD: Ischemic heart disease; NSAIDS: Non-steroidal anti-inflammatory drugs; PPI: Proton pump inhibitors.

Table 5 Association between previous surgery and diverticulosis after matching between patients with and without diverticulitis

Feature	Without diverticulitis, *n* = 59	With diverticulitis, *n* = 59	*P* value
Surgery	20 (66)	28 (52)	0.2
Ventral hernia	6 (10)	2 (3)	0.29
Inguinal hernia	10 (17)	10 (17)	> 0.99
Cholecystectomy	8 (13)	6 (10)	0.79
Gastric surgery	4 (7)	3 (1)	> 0.99
Appendectomy	5 (8)	8 (13)	0.58
Small bowel	0 (0)	0 (0)	0.34
Cesarean section	4 (7)	3 (5)	> 0.99
Gynecological	7 (12)	7 (12)	> 0.99
Urologic	2 (3)	0 (0)	> 0.99
Other	0 (0)	1 (2)	> 0.99

Data are *n* (%).

ARTICLE HIGHLIGHTS

Research background

Diverticulosis coli is one of the leading causes of morbidity in Western countries. Abnormal colonic pressure profiles have been associated with an increased risk of colonic diverticulosis.

Research motivation

Despite its high prevalence, the pathogenesis of colonic diverticulosis remains poorly understood.

Research objectives

We sought to assess whether previous abdominal surgery, presumably by means of adhesion-related increased colonic intraluminal pressure, is associated with colonic diverticulosis or diverticulitis.

Research methods

Patients undergoing colonoscopy completed a structured questionnaire concerning previous abdominal surgeries, dietary and lifestyle exposures including smoking and alcohol use, and co-morbidities. The presence of diverticulosis was identified *via* colonoscopy.

Research results

Three hundred and fifty-nine patients were included in the study. The overall prevalence of colonic diverticulosis was 25% (91/359) and 48% of the patients had previous abdominal surgery. There was no difference in the rate of previous abdominal surgery between patients with or without diverticulosis (49% *vs* 47%, $P = 0.78$). In regards to specific surgeries, inguinal hernia repair was significantly associated with diverticulosis (52% *vs* 20%, $P = 0.001$), but not diverticulitis. In contrast, appendectomy was not associated with diverticulosis (6% *vs* 14%, $P = 0.048$).

Research conclusions

These findings suggest that post-operative abdominal adhesions inducing high colonic intraluminal pressures do not appear to be the mechanism for diverticula formation. Rather, inguinal hernia and diverticulosis may share similar connective tissue pathologies with no causative relationship between them.

Research perspectives

The pathogenesis of colonic diverticulosis remains unclear and future studies are needed.

FOOTNOTES

Author contributions: Shirin H designed the research study; Ariam E, Richter V, Bermont A and Sandler Y performed the research; Ariam E, Cohen DL and Shirin H analyzed the data and wrote the manuscript; All authors have read and approve the final manuscript.

Institutional review board statement: The study was reviewed and approved by the Helsinki Committee of Shamir Medical Center (0107-20-ASF).

Informed consent statement: All study participants provided informed consent prior to study enrollment.

Conflict-of-interest statement: There are no conflicts of interest to report.

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ORCID number: Vered Richter 0000-0001-6003-9220; Anton Bermont 0000-0002-1343-8779; Daniel L Cohen 0000-0002-7879-3966; Haim Shirin 0000-0002-3375-4963.

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