Characteristics and associated risk factors of diverticular disease assessed by magnetic resonance imaging in subjects from a western general population

Short Title: Diverticular Disease assessed by MRI

Corinna Storz[1], MD; Theresa Rothenbacher[1]; Susanne Rospleszcz[2], MSc; Jakob Linseisen[2,3], MD; Helmut Messmann[4], MD; Carlo N. De Cecco[5], MD; Jürgen Machann[6,7,8], PhD; Roberto Lorbeer[9], PhD; Lena S. Kiefer[1], MD; Elke Wintermeyer[10], MD; Sophia Heber[1], MD; Konstantin Nikolaou[1], MD; Stefanie Elser[1], PhD; Wolfgang Rathmann[11], MD; Maximilan F. Reiser, MD[9]; Annette Peters[2,12,13,14], PhD; Christopher L. Schlett[15], MD MPH; Fabian Bamberg[1], MD MPH

[1]Department of Diagnostic and Interventional Radiology, University Hospital Tuebingen, Tuebingen, Germany.

[2]Institute of Epidemiology, Helmholtz Centre Munich, German Research Center for Environmental Health, Neuherberg, Germany.

[3]University Center of Health Sciences at Klinikum Augsburg (UNIKA-T), Ludwig-Maximilians University of Munich, Augsburg, Germany.

[4]Department of Internal Medicine III, Klinikum Augsburg, Augsburg, Germany.

[5]Department of Radiology, Medical University of South Carolina, Charleston, SC, USA

[6]Section on Experimental Radiology, Department of Diagnostic and Interventional Radiology, University Hospital Tuebingen, Tuebingen, Germany.

[7]Institute for Diabetes Research and Metabolic Diseases (IDM) of the Helmholtz Center Munich at the University of Tuebingen, Germany.

[8] German Center for Diabetes Research (DZD), Tuebingen, Germany.

[9] Department of Radiology, Ludwig-Maximilians-University Hospital, Munich, Germany.

[10] Siegfried Weller Institute for Trauma Research, BG Trauma Center Tübingen, Eberhard Karls University Tübingen, Germany.

[11] Department of Biometry and Epidemiology, German Diabetes Center, Duesseldorf, Germany.

[12] German Center for Cardiovascular Disease Research (DZHK e.V.), Munich, Germany.

[13]Institute for Cardiovascular Prevention, Ludwig-Maximilians-University-Hospital, Munich, Germany.

[14] Chair of Epidemiology, Ludwig-Maximilians-University, Munich, Germany

[15]Department of Radiology, Diagnostic and Interventional Radiology, University of Heidelberg, Heidelberg, Germany.

Correspondence: Corresponding author: Fabian Bamberg, MD MPH

Department of Diagnostic and Interventional Radiology

University Hospital Tuebingen

Hoppe-Seyler Str. 3

72076 Tuebingen, Germany

Email: fabian.bamberg@uni-tuebingen.de

Abstract

Objective: To study the prevalence, extent and distribution of asymptomatic diverticular disease by magnetic resonance imaging (MRI) in a sample of a Western general population.

Methods: Random subjects from a population-based cohort study who underwent 3 Tesla whole-body MRI were analyzed for the prevalence and extent of diverticula of the colon using an isotropic VIBE-Dixon gradient-echo sequence (TR 4.06 ms, TE 1.26, 2.49 ms, flip angle 9°). The extent of diverticular disease was categorized according to the number of diverticula in each colonic segment. Univariate and multivariate analysis was performed in order to assess associated characteristics and risk factors.

Results: Among 393 subjects included in the analysis (56.4 ± 9.2 years, 57.5% males), 164 (42%) had diverticular disease, with the highest prevalence in the left-sided colonic segments (93% had diverticular disease in the descending and sigmoid segment). Subjects with advanced diverticular disease were older (62.1 vs 54.4 years) and had a higher body mass index (BMI), LDL cholesterol levels and systolic blood pressure (30.2 ± 5.1 vs 27.8 ± 4.9 kg/m^2, 149.8 ± 29.3 vs 135.2 ± 32.9 mg/dL and 128.2 ± 14.1 vs 118.4 ± 16.1 mmHg, respectively), compared to subjects without diverticular disease, which remained significant after adjustment for BMI. In contrast, no significant correlation could be found for gender, physical activity, smoking status and alcohol consumption (all p>0.31). Intra-rater reproducibility was excellent for all colonic segments (intra class correlation (ICC)=0.99-1.00) and inter-rater reproducibility was excellent for left- and right sided colonic segments (ICC=0.84-0.97).

Conclusion: MRI may serve as a non-invasive and non-ionizing modality for the detection of asymptomatic diverticular disease, improving risk stratification in jeopardized subjects presenting with risk factors for diverticular disease.

Introduction

Colonic diverticular disease refers to multiple outpouches from the colonic lumen due to weakness of the muscular wall in the mucosa and harbors the risk of potentially life-threatening complications such as bleeding and inflammatory changes potentially leading to perforation and peritonitis (1-3) (4). Several studies reported previously, that the prevalence of diverticular disease increases with age ranging from 32.6% in 50-59 year old individuals to 71.4% by the age of 80 years and older. Since the elderly population grows, diverticular disease represents an increasing disease and healthcare burden worldwide, especially in western and industrialized countries (5).

The exact prevalence of asymptomatic diverticulosis is difficult to assess. Initial results of several large-scale clinical studies using colonoscopy or computed tomography indicate that the prevalence of diverticulosis is still increasing with a substantial set of risk factors promoting the development of diverticular disease (5, 8, 9). Diverticular disease seems to be associated with various factors such as colonic wall alterations or disordered motility, dietary habits, obesity, smoking and different medication (2, 3, 6, 7). Furthermore, early research indicates a genetic predisposition for the development of diverticular disease (10, 11). In approximately 10-25% of individuals with diverticulosis, inflammatory alterations with diverticulitis will occur (4, 12). This is partially in contrast to earlier clinical data in asymptomatic patients who underwent colonoscopies, indicating that only 4% of the individuals with asymptomatic diverticulosis developed later diverticulitis, while a higher risk for the progression of diverticular disease in younger patients was observed (13). However, studies about asymptomatic diverticular disease investigating the extent and distribution are scarce, particularly in a general population.

Magnetic resonance imaging (MRI) represents a non-invasive imaging modality without the need of radiation exposure, also for the evaluation of the gastrointestinal tract, including diverticular disease (14). With regard to the diagnostic of inflammatory diseases of the gastrointestinal tract, previous research showed that MRI is a feasible alternative modality to computed tomography (CT) in the diagnosis and evaluation of acute colonic diverticulitis with high sensitivity and specificity (14-18). However, there are no studies analyzing the presence and extent of asymptomatic diverticulosis by MRI.

Given the clinical relevance and still limited understanding of the associated pathophysiology of diverticulosis and diverticular disease, studies in larger populations are necessary to assess risk factors for the development of diverticular disease and potentially develop tailored prevention strategies. Therefore, the purpose of this study was to evaluate the characteristics of asymptomatic diverticular disease as assessed by MRI in an asymptomatic, population-based sample. Our hypothesis was that there are differences in distribution and distinct risk factors that are associated with diverticular disease.

Methods and Material

Study Design and Participants Recruitment

This study was designed as a case control study, embedded in a prospective cohort from the Cooperative Health Research in the Region of Augsburg (KORA), as described elsewhere (19). Participants were recruited from the follow-up of the KORA S4 study and were enrolled in a MRI sub-study between June 2013 and September 2014 at the KORA study center (19).

The study was approved by the institutional review board and all participants provided written informed consent. Details of the study design, inclusion and exclusion criteria as well as the MRI protocol have been provided elsewhere (19).

Covariates

In this study, baseline information on sociodemographic variables and risk factors were collected by comprehensive interviews and a medical examination in a standardized fashion (20). Body mass index (BMI) was defined as the value from the mass of the participant in kilogram divided by its height squared in meters. Smoking was defined as never-, ex- and current smoker. Alcohol consumption was defined according to the anamnesis as no (0 g/day), moderate (0.1–39.9 g/day for men and 0.1–19.9 g/day for women) and heavy alcohol consumption (>40 g/day for men and >20 g/day for women) (21). Subjects were categorized as physically active (regular physical activity ≥ 1h/week) or physically inactive (irregular physical activity < 1h/week, almost no physical activity and no physical activity at all). An oral glucose tolerance test (OGTT) was administered to all participants and established definitions of diabetes and prediabetes were applied (22). Specifically, prediabetes was defined as impaired glucose tolerance and/or impaired fasting glucose, healthy controls were defined as normal glucose metabolism by OGTT (23). Blood pressure was measured in the course of the KORA health study examinations, independent of the time of MRI acquisition. Hypertension was defined as increased systolic blood pressure ≥140 mmHg, increased diastolic blood pressure ≥90 mmHg or use of antihypertensive medication. Medication being antihypertensive by most recent guidelines was defined as ‘antihypertensive medication’ and lipid-lowering medication was defined as the routinely intake of statins, fibrates or other lipid lowering agents. Other established risk factors were collected in standardized fashion as part of the study design, as previously described (20).

Magnetic Resonance Imaging Protocol

All participants underwent an identical imaging protocol on a 3 Tesla Magnetom Skyra MRI (Siemens Healthineers, Erlangen, Germany), as detailed previously (20). For the assessment of diverticular disease, a two point T1 weighted isotropic Dixon-VIBE gradient-echo sequence of the abdomen was employed with the following parameters: TR 4.06 ms, TE 1.26, 2.49 ms, flip angle 9˚, partition thickness 1.7 mm, isotropic in-plane resolution 1.7 mm. This sequence acquires a total of 4 contrasts based on the chemical shift effect of water- and fat-bound protons, a) the in-phase, b) the opposed-phase, c) the water-only phase and d) the fat-only phase (Figure 1).

Magnetic Resonance Imaging Analysis

The MR images were assessed by two independent readers who were blinded for all clinical and demographical information about the participants. A colonic diverticulum was defined as an outpouche from the colonic lumen (4). Each reader recorded the number and location of the diverticula for each participant in the caecum, ascending colon, transverse colon, descending colon and sigmoid colon using a commercially available medical imaging viewer software (OsiriX, Pixmeo, Geneva, Switzerland). In line with previous research applying CT colonography, a graded-scale system was used to classify the extent of colonic diverticula (24) : grade 1 = no diverticular disease, grade 2 = mild diverticular disease with <6 diverticula in at least one colonic segment, grade 3 = advanced diverticular disease with ≥6 diverticula in at least one segment of the colon. With respect to the reliability, inter-rater and intra-rater variability was assessed by Intraclass Correlation Coefficient (ICC) analysis in a subset of 60 and 40 participants, respectively. Representative examples of participants with categorized diverticular disease are provided in Figure 2, examples for the applied diverticular disease grading scale are given in Figure 3.

Statistical Analysis

Subject demographics are reported as arithmetic means with standard deviation for continuous risk factors and as counts and percentages for categorical risk factors. Differences in risk factors between the stages of diverticular disease were assessed by one-way ANOVA and χ^2 -Test, accordingly. Stages of diverticular disease according to colonic segment are presented as counts and percentages. To analyze the association of risk factors for advanced diverticular disease, a logistic regression model containing the variables age, sex, BMI, systolic blood pressure, total cholesterol, LDL cholesterol and use of antihypertensive medication was calculated. Continuous variables were standardized to ensure the comparability of the resulting Odds Ratios (ORs). Two-sided P-values < 0.05 are considered to indicate statistical significance. All computations were done with R version 3.4.1.

Results

Among 400 Caucasian participants enrolled in this study, seven participants were excluded from the analysis due to impaired image quality (1.8%). Thus, 393 participants formed the study cohort, being predominantly middle-aged men (mean age: 56.4 ± 9.2 years, (57.5% males). Demographics of the study population are provided in Table 1.

Intra-rater and Inter-rater Reliability

Intra-rater reproducibility was excellent for all colonic segments ICC between 0.99 and 1.00) whereas inter-rater reproducibility was excellent for the right- and left sided colonic segments (ICC between 0.84 and 0.97).

Diverticular Distribution and Severity

Presence and distribution of diverticular disease are provided in Table 2. Absence of diverticular disease was observed in 229 (58.3%) participants, while in 164 participant diverticular disease was present (prevalence: 41.7 %). Among subjects with diverticular disease, the majority had mild disease and only a minority had advanced diverticular disease (24.2% vs. 17.6% for mild vs. advanced diverticular disease, respectively). Within the colon, the prevalence of diverticular was highest in the descending and sigmoid colon (41.0 % and 42.8% for the descending and sigmoid colon, respectively), whereas the caecum had the lowest prevalence of diverticula (0.7%).

Association of Diverticular Disease with Risk Factors

Subjects with diverticular disease were significantly older, ranging from a mean age of 54.4 ± 8.8 years in participants without diverticular disease to a mean age of 62.1 ± 7.7 years in participants with advanced diverticular disease ($p \leq 0.001$, Table 1). Furthermore, the grade of diverticular disease was significantly correlated with age (Figure 4). Similarly, subjects with advanced disease had significantly higher BMI as compared to the control group (BMI: 27.8 ± 4.9; 27.5 ± 4.6 and 30.2 ± 5.1 for participants without, mild and advanced diverticular disease, respectively; p=0.001; Figure 5).

Referring to laboratory results, total cholesterol as well as low-density-lipoprotein (LDL) cholesterol were significantly elevated in subjects with diverticular disease (p<0.03). Additionally, we found elevated systolic blood pressure as well as a higher proportion of intake of antihypertensive medication in subjects with diverticular disease with a presence of diverticula in the colon (all p<0.001). We did not find significant differences regarding diabetes status or lifestyle factors such as smoking and alcohol consumption as well as physical activity between subjects with and without diverticular disease (all p>0.3). Further demographics and risk profiles are provided in Table 1.

Comparing participants with diverticular disease only detected in the right-sided (n=12) versus left-sided colonic segments (n=129), subjects with left-sided diverticular disease are older and had significantly higher BMI levels (mean age: 51.4 ± 9.5 vs. 58.9 ± 8.9 years, mean BMI: 25.6 ± 4.9 vs. 28.8 ± 5.0 kg/m^2, for subjects with right-sided vs. right-sided diverticular disease, respectively; all p≤0.04). Furthermore, subjects with left-sided diverticular disease present higher levels of triglycerides and systolic blood pressure, as compared to those with right-sided diverticular disease (Triglycerides: 138.1 ± 76.5 vs. 92.2 ± 26.1 mg/dL and systolic blood pressure: 124.5 ± 18.1 vs. 110.6 ± 11.8 mmHg for left-sided vs. right-sided diverticular disease, respectively; all p≤0.04).

Comparing no or mild grade diverticular disease with advanced grade diverticular disease, age (OR: 2.24; 95%-CI:[1.60, 3.15], p <0.001), BMI (OR:1.44; 95%-CI:[1.06, 1.96], p = 0.02 and LDL cholesterol (OR:2.35, 95%-CI:[1.09, 5.06], p = 0.03) were associated with the presence of diverticular disease. This association remained significant after adjustment for BMI.

Discussion

In this study, we provide initial data on the presence and extent of diverticular disease in an asymptomatic, population-based study cohort using MRI. Our results indicate, that MRI may be an appropriate, non-invasive modality for the detection and characterization of asymptomatic diverticular disease with an excellent intra-rater and inter-rater reliability. Furthermore, our findings demonstrate a prevalence of 42% for asymptomatic diverticular disease in a western population, affecting predominantly the descending and sigmoid colon and being associated with higher age and cardiometabolic risk factors such as BMI and LDL cholesterol.

Although diverticular disease incurs several risk factors such as bleeding and inflammation, the exact prevalence of presupposed asymptomatic diverticular disease in a general population is unknown (4). Colonoscopy represents the current gold standard for the detection of diverticular disease. Previous studies showed that CT and CT colonography represent non-invasive modalities with excellent diagnostic accuracy, especially in symptomatic diverticular disease (25). Similarly to CT, MRI was previously shown to provide high sensitivity and specificity for diagnosis of colonic inflammatory bowel disease including symptomatic diverticular disease (14). However, data about asymptomatic diverticular disease is very limited and research regarding the detection of diverticula in the colon assessed by MRI is missing.

Most data on the prevalence of asymptomatic diverticular disease is based on incidental findings from invasive colonoscopy or CT colonography in a limited number of patients as well as from postmortem surveys. For example, Everhart et al. found a prevalence rate ranging from 32% to 71% according to age in a colonoscopy study (5). De Cecco et al. recently evaluated the extent and distribution of asymptomatic diverticular disease in a large population including 1,091 participants, assessed by computed tomography colonography, and found an overall prevalence of 47% (24). These findings are in line with our study results, as we found an overall prevalence of 42% for diverticular disease in our study population. Although this was a clinical cohort of mostly asymptomatic subject, we confirm the relatively high prevalence and extend these findings to the general population using MRI. Also, we confirm the predominance of diverticula to the descending and sigmoid colon (9, 24, 26). Interestingly, this is in contrast to earlier research stemming from Asian populations, in which a higher prevalence of diverticular disease of the right sided colon has been observed. That our population, a fully Caucasian sample, exhibits a more right-sided diverticulosis supports the racial variation hypothesis assuming that left sided diverticular disease is more common in the Western population (8, 9). It can be anticipated that these racial differences will also translate into the identification of genetic loci associated with diverticular disease, if imaging is implemented into larger-scale population-based studies, such as the German National Cohort or UK Biobank (27, 28).

Interestingly, our results showed no significant gender difference, which adds to the ongoing controversy on gender dependency of diverticular disease. Yamamichi et al. and Peery et al. found a preponderance of asymptomatic diverticular disease in males in a Japanese population and an American population, respectively (8, 26). Along with our results, De Cecco et al. found no significant difference between male and female participants in subjects with asymptomatic diverticular disease (24). In contrary, several former studies reported a higher prevalence of hospitalization due to diverticular disease in women (29, 30). Further, more outcome-related research will be necessary in order to determine whether gender serves as an effect modifier for the clinical manifestation of acute disease.

In addition, we found that age is a strong predictor of the presence and extent of diverticular disease. This is in line with earlier studies demonstrating that diverticular disease is more common in the elderly, also in an asymptomatic stage (5, 8, 9, 24). Furthermore, comparing participants with only right-sided diverticular disease with those with only left-sided diverticular disease, the latter group distinguish with significantly older subjects with higher levels of BMI, triglycerides and systolic blood pressure in our study. Additionally, as we found an association of the extent and distribution of diverticular disease in the left sided colonic segments according to increasing age, our results support the assumption that most of the diverticula recorded in the descending or sigmoid colon seem to be rather acquired than congenital. Furthermore left-sided diverticular disease seems to be strongly associated with age and metabolic risk factors, and there seems to be hereditary as well as pathophysiological differences concerning the development and distribution of diverticular disease in the colonic segments (26, 32, 33). However, as already mentioned above, previous research showed, that right-sided diverticular disease in western population does not seem to be such an uncommon finding as initially presumed (24). Thus, further large-scale population based research is warranted.

Our study results showed, that increased BMI, increased systolic blood pressure and high LDL cholesterol levels are associated with diverticular disease. In a retrospective case control study including participants who underwent colonoscopy, Kopylov et al. found out, that asymptomatic diverticular disease was associated with obesity (32). Given the ongoing and increasing demographic burden of obesity and other metabolic disorders, it will be relevant to further investigate interactions with obesity that confer increased risk for diverticular disease but ultimately acute diverticular disease. In addition, it will be objective of further, more focused research to identify modifiable factors such as nutrition that contribute to the development of diverticula.

Several studies reported an additional association of diverticular disease with alcohol consumption, smoking and diabetes. However, we found no significant association between the presence of diverticular disease and these cardiometabolic risk factors (7-9, 33). One explanation may be that our study population appears to be rather health-conscious, and participants with heavy smoking habits or alcohol consumption were scarce. Also, we report initial observations from a sample from the general population, which differs per se significantly from clinical cohorts and may exhibit different characteristics that may be more relevant in a preventive setting. However, further confirmatory research is mandatory. This may be particularly relevant as in symptomatic diverticular disease a higher risk for complications is predicted by smoking, increased alcohol consumption, obesity and physical inactivity (7, 34). For instance, Crowe et al. found an increased risk for hospitalization in smoking patients compared to non-smokers (6). In prior work, alcohol consumption was a predictive factor for severe and complicated diverticular disease, but this association was confounded by smoking status, which may highlight the important role of smoking as a major complicating risk factor in diverticular disease (6, 34, 35).

Previous studies found, that physical inactivity promotes the risk of inflammatory diverticular disease and conversely, that physical activity prevented diverticular disease and hospitalization (36-39). In a large 28-year follow-up study, Rosemar et al. observed a strong link between overweight and obesity and severe diverticular disease with consequential hospitalization in men (40). Accordingly, Strate et al. found especially central obesity as a strong predictive factor for complicated diverticular disease in men (3). Our results showed a higher prevalence of diverticular disease in obese subjects, however, there was no significant correlation between the presence of colonic diverticula and physical activity. One potential explanation may be that our assessment of physical activity was self-reported with well-known limitations and more detailed research is justified.

Our study has several limitations. The study was designed for the assessment of cardiometabolic multi-organ alterations, thus, participants were not prepared for specified gastrointestinal examination and did not receive preparation such as fibre-free diet, bowel cleansing, or oral/rectal preparation for fecal tagging prior to the MRI examination. However, while this may decrease the accuracy for detailed morphological assessment of single colonic diverticula, we firstly report its prevalence in a sample from the general, asymptomatic population, which precluded more complex and / or invasive preparations. As such, we were not able to prove accuracy of MRI by including an established gold-standard such as colonoscopy. However, we graded diverticular disease in broader categories, which may have attenuated inaccuracies inherent to MRI. Also, we found an excellent inter- and intra-rater reliability, but further studies comparing the detection of diverticula assessed by MRI with findings in colonoscopy are warranted.

In conclusion, MRI is a reproducible, low-risk imaging modality for the assessment of the presence and extent of diverticular disease in the general population. In our central European sample, the prevalence of diverticular disease is high and predominantly located in the descending and sigmoid colon. Subjects with advanced diverticular disease are older, have higher cholesterol levels and systolic blood pressure and are more obese, suggesting the central role of metabolic changes in the development of diverticular disease, whereas no significant differences were detected with respect to gender. Further research to elucidate the role of individual predisposition and risk for symptomatic diverticular disease and its complications in larger cohorts is warranted.

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Tables

Table 1. Patient demographic and risk factors according to the grade of diverticular disease

Variable	All	No diverticular disease	Mild diverticular disease	Advanced diverticular disease	p-value	p-value*
	N = 393	**N = 229 (58.3%)**	**N = 95 (24.2%)**	**N = 69 (17.6%)**		
Age (years)	56.4 ± 9.2	54.4 ± 8.8	56.9 ± 9.3	62.1 ± 7.7	<0.001	<0.001
Men	226 (57.5%)	128 (55.9%)	54 (56.8%)	44 (63.8%)	0.505	0.614
BMI (kg/m2)	28.1 ± 4.9	27.8 ± 4.9	27.5 ± 4.6	30.2 ± 5.1	0.001	0.001
normal	105 (26.7%)	63 (27.5%)	31 (32.6%)	11 (15.9%)	0.008	0.015
overweight	168 (42.7%)	101 (44.1%)	42 (44.2%)	25 (36.2%)		
obese	120 (30.5%)	65 (28.4%)	22 (23.2%)	33 (47.8%)		
Smoking						
never-smoker	144 (36.6%)	87 (38.0%)	35 (36.8%)	22 (31.9%)	0.394	0.435
ex-smoker	171 (43.5%)	96 (41.9%)	38 (40.0%)	37 (53.6%)		
smoker	78 (19.8%)	46 (20.1%)	22 (23.2%)	10 (14.5%)		
Diabetes status						

normoglycemic	238 (60.6%)	140 (61.1%)	61 (64.2%)	37 (53.6%)	0.540	0.664
prediabetes	101 (25.7%)	61 (26.6%)	21 (22.1%)	19 (27.5%)		
diabetes	54 (13.7%)	28 (12.2%)	13 (13.7%)	13 (18.8%)		
Total Cholesterol (mg/dL)	217.7 ± 36.5	213.8 ± 35.5	221.2 ± 40.0	225.9 ± 33.5	0.030	0.031
HDL Cholesterol (mg/dL)	61.9 ± 17.6	62.5 ± 17.8	63.4 ± 18.6	57.5 ± 15.0	0.073	0.076
LDL Cholesterol (mg(dL)	139.4 ± 33.0	135.2 ± 32.9	142.2 ± 34.0	149.8 ± 29.3	0.003	0.002
Triglycerides (mg/dL)	132.0 ± 85.3	129.2 ± 92.1	125.7 ± 78.4	149.8 ± 68.2	0.153	0.159
Systolic BP (mmHg)	120.7 ± 16.8	118.4 ± 16.1	120.9 ± 18.7	128.2 ± 14.1	<0.001	<0.001
Diastolic BP (mmHg)	75.3 ± 10.1	75.0 ± 9.2	74.5 ± 12.0	77.6 ± 9.6	0.112	0.120
Antihypertensive Medication	101 (25.7%)	43 (18.8%)	27 (28.4%)	31 (44.9%)	<0.001	<0.001
Physically active	234 (59.5%)	135 (59.0%)	55 (57.9%)	44 (63.8%)	0.722	1
Alcohol consumption						
no	94 (23.9%)	57 (24.9%)	20 (21.1%)	17 (24.6%)	0.308	0.313
moderate	222 (56.5%)	135 (59.0%)	53 (55.8%)	34 (49.3%)		
heavy	77 (19.6%)	37 (16.2%)	22 (23.2%)	18 (26.1%)		
NSAID	14 (3.6%)	6 (2.6%)	5 (5.3%)	3 (4.3%)	0.410	0.874

Antithrombotic medication	23 (5.9%)	6 (2.6%)	11 (11.6%)	6 (8.7%)	0.004	0.115

Data are means and standard deviations for continuous variables and counts and percentages for categorical variables.

* Comparison between advanced and no diverticular disease.

Table 2. Extent of diverticular disease in the study population according to age, colonic segment and grade of diverticular disease

Age, years	Patients, n (%)	Caecum		Ascending colon		Transverse colon			Descending colon			Sigmoid colon		
		no	**mild**	**no**	**mild**	**no**	**mild**	**advanced**	**no**	**mild**	**advanced**	**no**	**mild**	**advanced**
39-50	N = 127 (32.3%)	126 (99.2%)	1 (0.8%)	124 (97.6%)	3 (2.4%)	123 (96.9%)	4 (3.1%)	0 (0.0%)	101 (79.5%)	19 (15.0%)	7 (5.5%)	106 (83.5%)	16 (12.6%)	5 (3.9%)
51-60	N = 113 (28.8%)	113 (100.0%)	0 (0.0%)	108 (95.6%)	5 (4.4%)	109 (96.5%)	4 (3.5%)	0 (0.0%)	94 (83.2%)	15 (13.3%)	4 (3.5%)	85 (75.2%)	19 (16.8%)	9 (8.0%)
61-73	N = 153 (38.9%)	152 (99.3%)	1 (0.7%)	140 (91.5%)	13 (8.5%)	140 (91.5%)	11 (7.2%)	2 (1.3%)	87 (56.9%)	43 (28.1%)	23 (15.0%)	86 (56.2%)	21 (13.7%)	46 (30.1%)
all (% of total)	N=393	391 (99.5%)	2 (0.5%)	372 (94.7%)	21 (5.3%)	372 (94.7%)	19 (4.8%)	2 (0.5%)	282 (71.8%)	77 (19.6%)	34 (8.7%)	277 (70.5%)	56 (14.2%)	60 (15.3%)
p-value		1		0.070		0.212			<0.001			<0.001		

Data are counts and percentages.

Figures

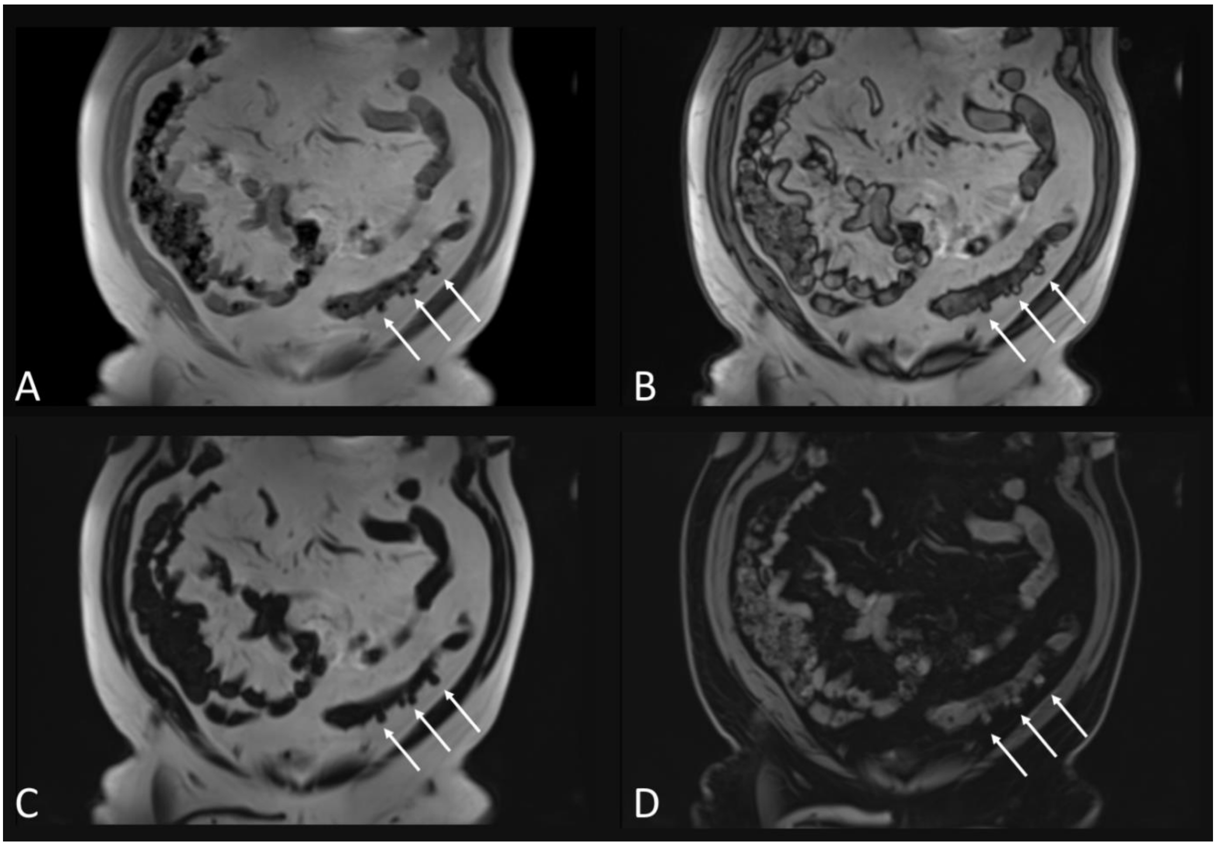

Figure 1. Example of MRI acquisition in a 57 year old male with advanced diverticular disease in the sigmoid colon by coronary multiplanar reconstruction of the T1 weighted Dixon-VIBE isotropic gradient-echo sequence in the in-phase (A), opposed-phase (B), fat-only (C) and water-only (D) images. The white arrows indicate the diverticula.

Figure 2. Example of a 77 year old female (A) and 64 year old male (B) with advanced diverticular disease (*white arrows*) in the sigmoid colon in coronary and axial multiplanar reconstruction. L=liver, K=kidney, S=spleen.

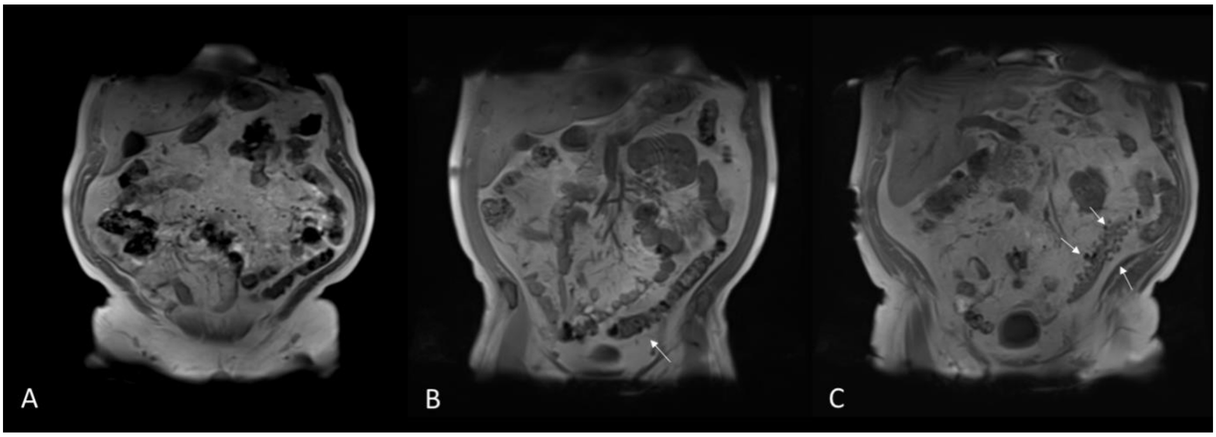

Figure 3. Extent of diverticular disease according to the grading scale. A: grade 1 = no diverticular disease, B: grade 2 = mild diverticular disease with <6 diverticula (*white arrow*) in at least one colonic segment and C: grade 3 = advanced diverticular disease with ≥6 diverticula in at least one segment of the colon.

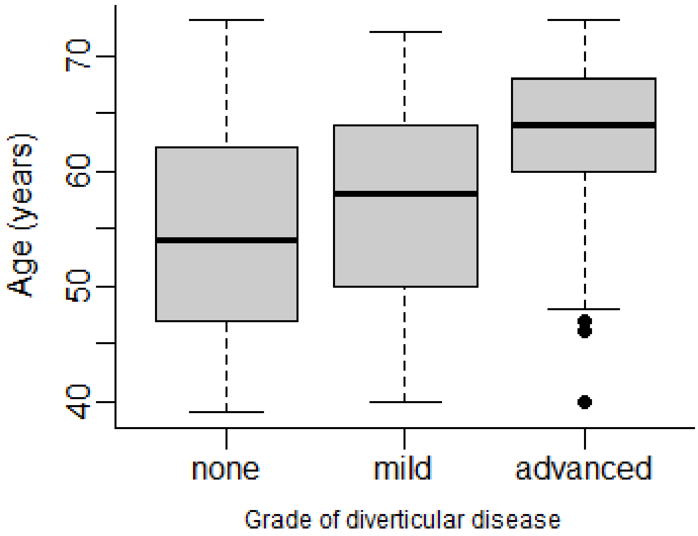

Figure 4. Grade of diverticular disease according to age.

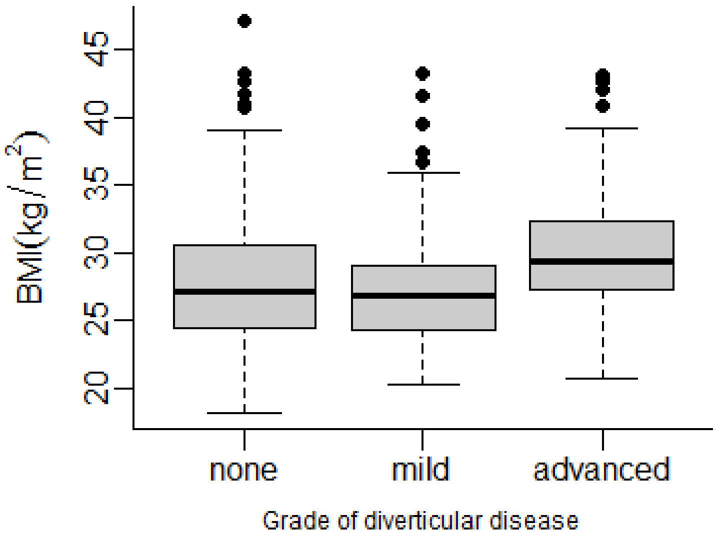

Figure 5. Grade of diverticular disease according to BMI.