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Research article

Preoperative assessment of splenic involvement in patients with peritoneal carcinomatosis with CT and MR imaging

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ABSTRACT

Purpose: To estimate the performances of computed tomography (CT) and magnetic resonance imaging (MRI) and those of the combination of CT with MRI in the identification of splenic involvement in patients with peritoneal carcinomatosis (PC).

Material and method: CT and MRI examinations of 26 patients with PC with splenic involvement and 26 patients with PC and no splenic involvement treated by total cytoreductive surgery (CRS) and hyperthermic intraperitoneal chemotherapy (HIPEC) were reviewed. There were 32 women and 20 men with a mean age of 53.44 ± 12.22 (SD) years (range: 20–73 years). Imaging examinations were reviewed separately as three independent imaging sets (CT only, MRI only and CT with MRI) by two independent readers. A consensus was reached during a joint reading session and these results were used for determining the performances of the three imaging sets in the diagnosis of splenic involvement using surgical and histopathological findings as standard of reference.

Results: Splenic involvement was histologically proven in 26/52 patients (50%). There were no significant differences in sensitivity, specificity and accuracy for the diagnosis of splenic involvement between CT, MRI and CT + MRI, with respectively 84.62%, 96.15% and 90.00% for CT, 84.62%, 84.62% and 85.00% for MRI and 92.31%, 92.31% and 92.00% for CT + MRI.

Conclusion: CT and MRI have similar sensitivities, specificites and accuracies for the diagnosis of splenic involvement in patients with PC. The combination of CT and MRI does not significantly improve the preoperative diagnosis of splenic involvement in patients with PC compared to CT only.

1. Introduction

Peritoneal carcinomatosis (PC) affects 70% of patients with ovarian tumor, 30% of those with appendicular tumor, 17% of those with gastric cancer and 8–15% of those with colorectal cancer [1–4]. PC conveys a poor outcome with a median overall survival of 6 months in the absence of treatment [5,6]. However, substantial variations exist depending on the nature of the primary tumor. In this regard, a five-year survival rate < 5% has been reported for patients with PC from gastric cancer [7] in contrast with up to 50% for those with pseudomyxoma peritonei [8].

When feasible, the combination of total cytoreductive surgery (CRS) with hyperthermic intraperitoneal chemotherapy (HIPEC) is now the treatment of reference for patients with PC from colorectal and ovarian cancer as well as for those with rare peritoneal diseases [6,9,10]. In the same time, CRS with HIPEC is now used for the treatment of PC from other primary tumors [11–14], thus substantially prolonging the survival of patients [15,16].

Abbreviations: CRS, cytoreductive surgery; CT, computed tomography; HIPEC, hyperthermic intra peritoneal chemotherapy; MRI, magnetic resonance imaging; PC, peritoneal carcinomatosis; PCI, peritoneal carcinomatosis index

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Interestingly, it has been recently reported that splenectomy is associated an increased rate in postoperative complications in patients with PC treated by CRS + HIPEC compared to those who have no splenic involvement and do not require splenectomy [17]. In patients with PC, the role of preoperative imaging is to depict accurately the extent of the disease quantitatively and qualitatively. Several studies have evaluated the performances of computed tomography (CT) and those of magnetic resonance imaging (MRI) for the depiction of peritoneal nodules and organ involvement by PC [18–21]. Researchers have identified the respective capabilities of CT and MRI in determining the extent of the disease in patients with PC. However, no studies have specifically investigated the role of CT and that of MRI in the preoperative detection of splenic involvement in patients with PC.

The purpose of this study was to estimate the performances of CT and MRI and those of the combination of CT with MRI in the identification of splenic involvement in patients with PC.

2. Materials and methods

2.1. Patients

This single-center retrospective study was approved by our Institutional Review Board. The requirement for informed consent was waived. The database of our institution was queried to identify all consecutive patients with PC who had undergone CRS + HIPEC between April 2008 and August 2016 after a multidisciplinary tumor board meeting with a radiologist, a surgeon, an oncologist and a pathologist. A total of 357 patients were initially identified. Patients were further included in the study when (*i*), they have undergone CRS + HIPEC for PC; (*ii*), they have undergone splenectomy because of splenic involvement; (*iii*), they had pre-operative CT and MRI examinations available for review and (*iiii*), CT and MRI examinations were technically acceptable and performed less than 90 days before CRS with HIPEC. Image technical quality was defined as a full coverage of the whole left abdominal quadrant including the diaphragmatic cupola, a CT with at least a contrast-enhanced acquisition, a MRI with at least T2-weighted, diffusion-weighted and contrast-enhanced sequences. Patients with blurry images resulting for respiration artifacts and those with imaging examinations that did not cover the whole left abdominal quadrant were excluded. A total of 26 patients met the inclusion criteria and were ultimately included (Fig. 1). There were 17 women and 9 men, with a mean age of 54.5 ± 12.7 (SD) years (range: 20–73 years). This group of patients was further referred to as group 1.

A control group (group 2) was identified, which consisted of 26 patients who had undergone CT and MRI examination during the same period for PC before CRS + HIPEC. There were 15 women and 11 men with a mean age of 52.4 ± 11.8 (SD) years (range: 26–68 years) who were confirmed as having no splenic involvement at the time of surgery and did not undergone splenectomy.

2.2. Imaging techniques

2.2.1. CT technique

CT examinations were performed while the patient was in the supine position. A single-source multidetector CT unit (Somatom Sensation 64®, Siemens Healthineers, Forscheim, Germany) was used with the following parameters: configuration = 64 × 0.6 mm; beam collimation = 38.4 mm; peak tube potential = 120 kVp; gantry revolution time = 0.5 s; gantry rotation table speed = 46 mm; and beam pitch = 1.2. An online real-time attenuation-based tube current modulation technique (Care Dose®; Siemens Healthineers) was used with a tube current of 120–170 effective mAs. After unenhanced image acquisition, the patients received 100–120 mL of intravenous nonionic iodinated contrast material via an automated power injector (MedRad, Pittsburgh, PA, USA) at a rate of 3 mL/sec. The delay between the start of contrast material injection and the start of image acquisition was 70 s. CT was performed from the hepatic dome to the symphysis pubis in a cephalocaudal direction during one breath hold. No arterial or delayed phases were performed because of the poorly vascular type of PC (ovarian, colorectal, gastric, appendix cancer, pseudomyxoma peritonii and mesothelioma)

2.2.2. MRI technique

All patients underwent MRI examination of the abdomen and pelvis using a 1.5-T system (Magnetom Avanto®, Siemens Healthineers, running software Syngo MR VB17) after a fasting period of 12 h. All patients had intravenous injection of 0.5 mg of glucagon (Glucagen®, NovoNordisk) at the beginning of the examination and just before gadolinium-chelate injection to limit intestinal peristalsis. No oral application of water for intestinal distension was performed. The gradient strength of the magnet was 45-mT/m with a maximal gradient slope of 200 T/m/s.

MRI examinations included high-resolution free-breathing fat-suppressed T2-weighted turbo spin-echo (TSE) (TR/TE = 3000/88 msec; matrix size = 230 × 384; section thickness = 7 mm; field of view = 340–360 mm) sequence with respiratory triggering using prospective acquisition correction (PACE) in the transverse and coronal planes; fat-suppressed three-dimensional volumetric interpolated breath-hold gradient-echo (3D VIBE; TR/TE = 5.4/1.8 msec; flip angle = 10; section thickness = 3 mm; matrix size = 166 × 320; field of view = 340–400 mm) sequence before and 30, 60, 120 s and 5 min after intravenous administration of 10 mL of a gadolinium-chelate (gadoterate meglumine, Dotarem®, Laboratoires Guerbet, Roissy-Charles de Gaulle, France) in the transverse and coronal planes. In addition all patients had diffusion-weighted MRI with a free-breathing acquisition with respiratory triggering before intravenous injection of gadolinium-chelate, with a fat-attenuated single-shot echo-planar diffusion-weighted technique in the transverse plane (TR/TE = 5300/75 msec; b = 0, 500, 1000s/mm^2) and transverse and coronal T2-weighted half-Fourier acquisition single-shot turbo spin-echo (HASTE) (TR/TE = infinite/80 msec; matrix size = 320 × 226 ; section thickness = 7 mm; field of view = 400 mm) sequence.

2.3. Image analysis

Two radiologists with 10- (reader 1) and 4-years (reader 2) of experience in abdominal imaging, and 4 and 2 years of experience in PC imaging, independently analyzed pre-operative CT and MRI examinations with an interval of 3 weeks between each reading session. A first reading session was performed to analyze CT images only. A second reading session was performed to analyze MR images only. A third reading session was performed to analyze jointly CT and MR images. The results of these three separate reading sessions were used to estimate interobserver agreement for the evaluation of CT, MRI and CT + MRI examinations. Then a consensus was reached between the two readers during a joint reading session for each imaging set and these results were used for determining the performances of imaging in the diagnosis of splenic involvement. All reading sessions were performed blinded to the results of surgery and those of histopathological analysis. CT and MRI examinations were reviewed using a picture archiving and communication system (PACS) workstation (Carestream Health V12.1, Rochester, NY, USA).

Splenic involvement was considered in the presence of intrasplenic or perisplenic involvement. Intrasplenic involvement was considered in the presence of intrasplenic hypoattenuating masses, heterogeneous with cystic or necrotic components (Fig. 2). Perisplenic involvement was considered present when a scalloping of splenic boundaries or close relationships between the splenic capsule and PC nodules (of the left diaphragm, the left parieto-colic gutter, the pancreatic tail, the splenic hilum, the splenorenal and the gastro-splenic spaces) were identified on imaging. Ill-defined, soft tissue nodules or loculated ascites were considered as PC (Fig. 3). Intrasplenic homogeneous and well-marginated

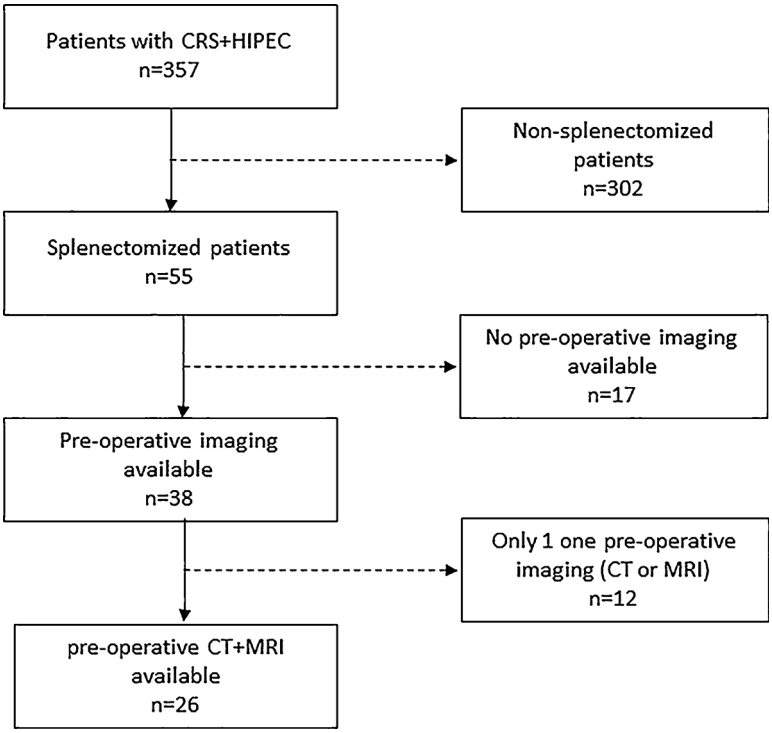

Fig. 1. Flow diagram shows information about inclusion and exclusion criteria to ultimately include 26 patients with peritoneal carcinomatosis and splenic involvement.

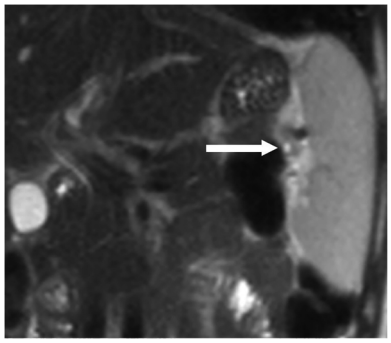

Fig. 2. 20-year-old woman with peritoneal carcinomatosis from ovarian tumor and splenic involvement. T2-weighted MR image in the coronal plane shows hyperintense sub centimeter tumor deposit (arrow) at the splenic hilum. The lesion was considered present by only one reader and overlooked by the other reader.

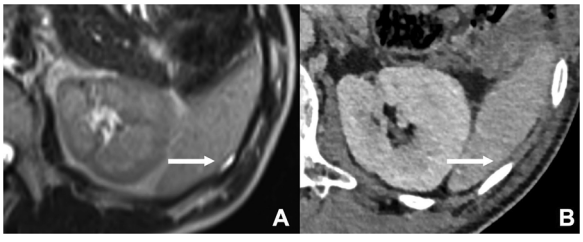

Fig. 3. 46-year-old man with peritoneal carcinomatosis from mucinous tumor of the appendix and splenic involvement. T2-weighted MR image in the transverse plane reveals perisplenic mucinous implant (arrow) (A). No lesion is visible on CT image in the same area (arrow) (B).

purely cystic lesions and hemangiomas were identified and excluded. Only one imaging criterion was necessary to consider splenic involvement.

To compare the 2 groups of patients and to identify imaging findings possibly associated with splenic involvement, the dimensions of the spleen (2 transverse diameters and height) were measured, the splenic volume with the following formula [22]: V = π (LxWxT)/4 (with V = volume, L = length, W = width, T = thickness) was calculated and perisplenic effusion, left pleural effusion and presence of accessory spleen were searched for. Peritoneal carcinomatosis index (PCI) was collected from the CRS + HIPEC operative reports.

2.4. Standard of reference

The causes of splenectomy as well as the number of splenic tumor foci were collected from the CRS + HIPEC operative reports [23]. During surgery, intraoperative inspection was carefully performed with respect to the presence of splenic involvement. Number, location and visual presentation of splenic tumor foci were collected.

After splenectomy, surgical specimens were fixed in formol, then included in paraffin for microtome cutting and spread on slide for a microscopic description. Immunohistochemical study using ABC-peroxydase method with a Ventana Benchmark automaton was performed.

2.5. Statistical analyses

Statistical analyses were performed by using GraphPad Prism (version 7.00, GraphPad Software, La Jolla California USA) and R (version 3.4.1 GNU GPL software, Vienna, Austria). Qualitative variables were expressed as raw numbers, proportions and percentages and compared using Fisher exact test. Quantitative variables were expressed as mean, standard deviation (SD) and range. Sensitivity, specificity and accuracy were calculated for each reader and expressed as percentages with their 95% exact confidence intervals. The Wilcoxon test was used to search for differences in quantitative variables. Performances of the different sets were compared using the McNemar test. Inter-observer agreement for the diagnosis of splenic involvement between radiologists and histopathological finding was assessed using the Cohen's kappa test. Kappa = 0.00–0.20 indicated slight agreement; kappa = 0.21–0.40 indicated fair agreement; kappa = 0.41–0.60 indicated moderate

Table 1
Patients characteristics (qualitative variables).

Variables	n (%)		*P*
	Splenic or perisplenic involvement	Controls	
Women	17 (17/26; 65.4%)	15 (15/26; 57.7%)	0.78
Primary tumor			0.08
Appendix	2 (2/26; 7.7%)	3 (3/26; 11.5%)	
Peritoneal desmoplastic small round cell tumor	2 (2/26; 7.7%)	0 (0/26; 0.0%)	
Colon	1 (1/26; 3.9%)	15 (15/26; 57.7%)	
Stomach	8 (8/26; 30.8%)	0 (0/26; 0.0%)	
Ovary	2 (2/26; 7.7%)	4 (4/26; 15.4%)	
Pseudomyxoma	11 (11/26; 42.1%)	(4/26; 15.4%)	
Left pleural effusion	1 (1/26; 3.9%)	0 (0/26; 0.0%)	0.99
Accessory spleen	1(1/26; 3.9%)	4 (4/26; 15.4%)	0.35
Perisplenic effusion	6 (6/26; 23.1%)	0 (0/26; 0.0%)	0.03

Note: Data are expressed as raw numbers. Numbers in parentheses are proportions followed by percentages.

agreement; kappa = 0.61–0.80 indicated substantial agreement; kappa = 0.81–1.00 indicated almost perfect agreement.

3. Results

The 2 groups of patients (i.e., those with splenic involvement and those without splenic involvement) were significantly different for the presence of perisplenic effusion (p = 0.03) and PCI (p = 0.0003). No differences in gender, age, left pleural effusion, accessory spleen, waiting period between imaging and surgery, and splenic volume were found between the 2 groups (Tables 1 and 2).

A perfect interobserver agreement was found between the two radiologists for the presence of splenic involvement using CT (Kappa = 1; 95% CI: 1.00–1.00). An almost perfect interobserver agreement was found for MRI (Kappa = 0.92; 95% CI: 0.84–1.01) (Fig. 2) and for CT + MRI (Kappa = 0.89; 95% CI: 0.78–0.99) (Fig. 2).

The sensitivity, specificity and accuracy of each imaging set for both readers are reported in Table 3. The results of the consensus reading were the same as those of reader 1.

There were no significant differences in sensitivity between the three imaging sets for reader 1 and reader 2. There was a 0% difference for reader 1 and a 7.7% difference in sensitivity for reader 2 between CT and MRI (p = 0.62 and p = 0.68, respectively). There was a 7.69% difference in sensitivity for both readers between CT and CT + MRI (p = 0.48). There was a 7.69% difference in sensitivity for reader 1 and a 15.39% difference for reader 2 between MRI and CT + MRI (p = 0.48 and p = 0.13, respectively).

There were no significant differences in specificity between the three imaging sets for both readers. There was an 11.53% difference in specificity between CT and MRI for both readers (p = 0.25 for reader 1 and p = 0.37 for reader 2). There was a 3.84% difference in specificity for reader 1 and a 15.38% difference for reader 2 between CT and CT + MRI (p = 1 and p = 0.13, respectively). There was a 7.69% difference in specificity for reader 1 and a 3.85% difference for reader 2 between MRI and CT + MRI (p = 0.48 and p = 1, respectively).

There was a total of 4 false-negative findings in 4 individual patients with CT alone for both readers. These 4 false-negative findings were observed in the same 4 patients by both readers. Of these, 2 false negatives were found in 2 patients with a long waiting period between CT and surgery (72 and 90 days) and 2 false-negatives in 2 patients with tiny tumor deposits on the splenic capsular surface at surgery (Fig. 3)

There was a total of 4 false-negative findings in 4 individual patients with MRI alone for reader 1 and 6 false-negative findings in 6 individual patients for reader 2 (Fig. 4). Three false-negative findings were observed in the same 3 patients by both readers. Among the 7 individual patients with false-negative findings, one patient had a waiting period of 61 days between MRI and surgery, 2 patients had tiny lesions on the splenic capsular surface found at pathology, one patient had an infra millimetric tumor deposit at the splenic hilum, 2 patients had a limited perisplenic effusion and one patient had a splenic capsular lesion of 2 mm.

There was of total of 2 false-negative findings with CT + MRI in 2 individual patients for both readers. These 2 false-negative findings were observed in the same 2 patients by both readers. These two patients had tiny tumor deposits on the capsular surface of the spleen at surgery that were confirmed at histopathological analysis.

There was only 1 false-positive finding with CT alone in one individual patient for both readers. This false-positive finding was observed in the same patient by both readers. This patient had multiple accessory spleens erroneously considered as tumor nodules at imaging and further confirmed as accessory spleens at surgery.

There was a total of 4 false-positive findings with MRI alone in individual 4 patients for both readers. These 4 false-positive findings were observed in the same 4 patient by both readers Two patients had a left colic flexure infiltration that did not involve the spleen at surgery, one patient had a left diaphragm thickening with no tumor at surgery and one patient had a sub centimeter splenic capsular lesion, not found during surgery.

There was a total of 2 false-positive findings in 2 individual patients with CT + MRI for reader 1 and 5 false-positive findings in 5 individual patients for reader 2. Two false-positive findings were observed in the same two patients for both readers. Among the 5 individual patients with false-positive findings, one patient was the patient with false-positive finding with CT alone and the other 4 patients were those with

Table 2
Patients characteristics (quantitative variables).

Variables	Splenic involvement	Controls	*P*
PCI	20.65 ± 10.52 [3–39]	8.73 ± 5.46 [0–21]	< 0.001
Delay CT – surgery (day)	21.73 ± 38.83 [1–90]	12.77 ± 17.96 [1–63]	0.44
Delay MRI – surgery (day)	16.96 ± 37.30 [1–90]	6.00 ± 11.79 [1–53]	0.35
Age (year)	54.46 ± 12.68 [20–73]	52.42 ± 11.77 [–68]	0.63
Splenic volume (cm [3])	35.69 ± 20.61 [11.38–94.91]	41.31 ± 23.62 [6.75–90.67]	0.45

Note: PCI indicates peritoneal carcinomatosis index. Data are expressed as mean ± standard deviation Numbers in brackets are ranges.

Table 3
Sensitivity, specificity and accuracy values for the detection of splenic involvement for each set of reading, for each reader using the combination of surgical and pathological findings as gold standard.

		TP	TN	FP	FN	Sensitivity	Specificity	Accuracy
Reader 1 = consensus reading	CT	22	25	1	4	84.62 % [0.65–0.96]	96.15 % [0.80–0.99]	0.90 [0.79–0.97]
	MRI	22	22	4	4	84.62 % [0.65–0.96]	84.62 % [0.65–0.96]	0.85 [0.72–0.93]
	CT + MRI	24	24	2	2	92.31 % [0.75–0.99]	92.31 % [0.75–0.99]	0.92 [0.81-0.98]
Reader 2	CT	22	25	1	4	84.62 % [0.65–0.96]	96.15 % [0.80–0.99]	0.90 [0.79–0.97]
	MRI	20	22	4	6	76.92 % [0.56–0.91]	84.62 % [0.65–0.96]	0.81 [0.67–0.90]
	CT + MRI	24	21	5	2	92.31 % [0.75–0.99]	80.77 % [0.61–0.93]	0.87 [0.74–0.94]

Note: TP means true positive, TN means true negative, FP means false positive and FN means false negative. Numbers in brackets are 95% confidence intervals.

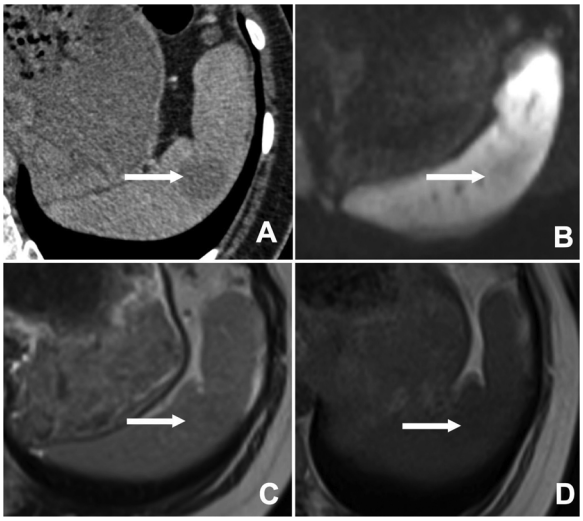

Fig. 4. 39-year-old man with peritoneal carcinomatosis from colic adenocarcinoma and splenic involvement. A solid intrasplenic lesion (arrow) was visualized on CT image by two independent readers (A) whereas no lesion was visible on diffusion-weighted MRI (B), T2-weighted MRI (C) or T1-weighted MRI (D) by the same two independent readers. PC was confirmed at pathological examination.

false-positive findings with MRI alone.

4. Discussion

In this study, we found high degrees of performances for the diagnosis of splenic involvement in patients with PC using CT and MRI with a sensitivity ranging from 76.92% to 92.31%, a specificity from 80.77% to 96.15% and an accuracy from 81% to 92%. Previous studies have shown a sensitivity with CT ranging from 49% to 93% and a specificity from 78% to 96.2% for all quadrants together [18,19,24–27]. For MRI, sensitivity was 88% to 95% and specificity ranged from 70% to 91% [18–20]. Only one study that analyzed the combination of CT with MRI found a sensitivity ranging from 62% to 67% [21].

In some studies, researchers have reported results according to the abdomen's quadrants as defined by Sugarbaker [28,29]. With CT, for left hypochondrium, sensitivity ranged from 40% to 86% and specificity ranged from 83% to 91%; for left lumbar region, sensitivity ranged from 43% to 73% and specificity from 89% to 100% [19,21,30,31]. With MRI, for left hypochondrium, sensitivity ranged from 86% to 94% and specificity from 83% to 92%; for the left lumbar, sensitivity ranged from 74% to 93% and specificity ranged from 75% to 79% [19,20]. With the combination of CT + MRI, sensitivity was 81% for the left hypochondrium and varied from 50 to 64% for the left lumbar region [21].

Other studies have differentiated, within the left hypochondrium, the splenic surface, the left diaphragmatic cupola, and the left parieto-colic gutter in the left lumbar region metastasis. With CT, sensitivity and specificity were respectively of 67–100% and 86–92% for the splenic surface, 50–78% and 79–92% for the left diaphragm and 73–75% and 77–86% for the left parieto-colic gutter [18,24]. With MRI, sensitivity and specificity were respectively of 0% and 95% for the splenic surface, 67% and 95% for the left diaphragmatic cupola and 100% and 95% for the left parieto-colic gutter [18].

In our study, the delay between imaging and surgery (CRS + HIPEC) was on average 19 days. Some studies have reported shorter delay, with preoperative imaging performed less than 21 days before surgery [21,27,32] but most of them had similar intervals ranging from 1 to 119 days [19,24–26,31,33].

Most studies have reported that MRI is more sensitive but less specific than CT in the preoperative assessment of PC. In the study of Low et al. MRI was significantly more sensitive (95%) than CT (55%) but less specific (70% versus 86%) for PC detection [19]. In the study by Dohan et al, CT combined with MRI improved PC's detection of left hypochondrium (81% versus 44–63%) compared with CT only [21]. Torkzad et al. did not find any difference in term of PCI between CT and MRI [32]. In our study we did not find an advantage of MRI over CT for the diagnosis of splenic or perisplenic PC. Despite the superiority of MRI for tissue characterization relying on water or fat content, perfusion and water diffusibility, the diagnostic performances of single portal venous phase CT and those of MRI for PC were similar. On the other hand, CT provides superior special resolution, which is a clear asset in patients with PC who frequently have micronodular tumor spread on the peritoneal surface. Although no patients had benign intrasplenic conditions in our study, it is reasonable to assume that the combination of CT and MRI would provide better degrees of characterization.

The performances of CT may be jeopardized by the presence of tiny peritoneal deposits. Coakley et al. reported a sensitivity of 85–93% for PC detection of ovarian origin [26]. This sensitivity dropped to 25–50% for lesions smaller than 1 cm. For Marin et al., the sensitivity of CT was 100% for lesions greater than 5 cm, 87% for lesions between 0.5 and 5 cm and 43% for lesions smaller than 5 mm [24]. Generally, diffusion-weighted MRI improves the detection of peritoneal implants, by increasing the contrast between spontaneously hyperintense tumor and adjacent healthy tissues [33–35]. However, the spleen is a spontaneously hyperintense organ on diffusion-weighted MRI, thus limiting the potential added value of diffusion-weighted MRI for the detection of perisplenic implants. Nevertheless, routine MRI protocol should include diffusion-weighted images to improve diagnostic performances of PC in other locations such as the right diaphragm, the pelvis, the liver or the omentum.

Torkvad et al. found similar sensitivities for PC detection with CT and MRI when images were read by the experienced radiologist. The less experienced radiologist had better results with CT [32]. However, in our study, imaging results were similar for both readers.

In our study, the two groups of patients were significantly different regarding PCI. Splenectomized patients of our cohort had a greater PCI compared to the control group. This can be explained by the mechanisms of PC dissemination. Indeed, PC preferentially spreads around the primitive tumor and because of the complete redistribution mechanism, in sloping and low peristalstism areas [36]. PC does not spread in the left hypochondrium at the beginning of the disease. When there is PC in the left hypochondrium, PCI is usually high. However, the number of areas involved by PC or the PCI does not influence the detection of splenic involvement.

The spleen plays an important immune role and its resection can lead to severe complications [37]. In the study by Dagbert et al., patients who underwent splenectomy had significantly more post-operative complications (59%) than non-splenectomized patients (35.9%), in particular pulmonary complications [17]. In a series of 112 patients, only 31% of them with post-splenectomy infection had previously received pneumococcal vaccination [38]. It seems necessary to identify patients at risk of splenectomy, in order to vaccinate them before surgery when splenectomy can be anticipated on the basis of imaging findings.

Several limitations may be raised with respect to our study. One relates to the relatively small number of patients, so that further studies including more patients are needed to fully determine the respective capabilities of CT and MRI in the detection of splenic involvement in patients with PC. Another limitation is a relatively long delay between imaging and surgery in three patients with false negative findings, thus potentially underestimating the actual performances of imaging.

In conclusion, CT and MRI have similar sensitivities, specificities and accuracies for the diagnosis of splenic involvement in patients with PC. The combination of CT and MRI does not significantly improve the preoperative diagnosis of splenic involvement in patients with PC compared to CT only. Our results support the use of CT as the first line imaging modality for spleen assessment in PC because of its accessibility and cost by comparison with MRI.

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