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Hydrocolonic Sonography. A Forgotten Technique

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1. Abstract

1.1. Objectives: Study of the sensitivity of Hydrocolonic Sonography (HS) in the detection of colonic lesions and how hydrocolonic sonography with echographic contrast agent (HSEC) can improve this technique.

1.2. Methods: A prospective study of 73 patients (65 by HS and 8 by HSEC). Sixty-five HS examinations were made prior to optical colonoscopy (OC). The results obtained by HS were compared with those of OC. In the 8 HSEC studies no cleaning preparation was used and all patients were awaiting surgery for colon tumours. An anatomopathological study of the lesions was carried out. Statistical significance was tested using ANOVA.

1.3. Results: In lesions of ≤ 5 mm, the HS had a sensitivity of 15.9% and a specificity of 100%; for lesions of 6-10 mm, the sensitivity was 70 % with a specificity of 96.1%. In lesions measuring over 10 mm the sensitivity was 93% and the specificity was 95.1%. In adenocarcinomas both parameters reached 100%. HS did not detect rectal lesions or flat lesions. All lesions studied by HSEC were enhanced, 88.9% were completely visualized, while with HS only 33.3% were fully observed. Five neoplasms were stenosing. Of the 10 lesions prior to the stenosis, those measuring 10 mm or more were detected, but not those of 5mm or less. There was a direct proportional relationship between size and degree of histological severity ($p < 0.05$).

1.4. Conclusions: HS is a technique with high sensitivity and specificity for lesions larger than 10 mm. HSEC improves the visualization of HS.

2. Introduction

Optical Colonoscopy (OC) is the gold standard technique in the diagnosis of colorectal cancer, as it allows the detection, biopsy and extraction of lesions. Imaging techniques such as MR or CT are used primarily at the tumour stage. Furthermore, CT-conolography has replaced barium enemas after incomplete colonoscopies, as recommended by the American Gastroenterology Association, since 2006 [1].

By contrast, the use of ultrasound in the detection of lesions of the colon is not widespread, since the findings described, such as wall thickening, irregular hypoechoic wall, and / or loss of stratification [2, 3], frequently correspond to advanced stages of the disease. Its

main limitation is the presence of intracolonic gas, which prevents the correct visualization of the colonic wall. However, this gas can be removed by the retrograde instillation of a water or saline solution in the colon as an enema [2-12]. This technique called Hydrocolonic Sonography (HS), fills and relaxes the colon, significantly improving its visualization.

3. Material and Methods

We present a prospective study of 73 patients (34 women and 39 men), with an average age of 61 and a range of 39 to 88. Seventy-three ultrasounds, 65 hydrocolonic sonographies (HS) and 8 hydrocolonic sonographies with echographic contrast agent (HSEC) were performed. Of the 65 HS, 64 corresponded to patients in the colorectal cancer screening program and 1 to a patient with a family history of polyposis. The HS was performed on the same day and two hours before the OC, so that the patients had already undergone the cleaning preparation. The bowel preparation included a low-residue diet for 72 hours prior to the test, a liquid diet 24 hours prior to the test and taking an evacuating solution (polyethylene glycol). No cleaning preparation was used for the HSEC and the patients were awaiting surgery for colon tumours, also the sonographer was unaware of the location, type and number of lesions. A single charge of Sono-Vue® was used as the echographic contrast agent, which is a second-generation contrast agent formed of sulphur hexafluoride microbubbles.

To distend the colon, a warm saline solution bag was placed on a drip stand 150-180 cm high. The bag was attached to an infusion system anastomosed to a balloon-catheter probe. The amount of saline solution depended on tolerance, but ranged from 1200 to 2000 ml. In lateral decubitus, the patient was catheterised and once the balloon catheter had been introduced into the rectal ampulla, the balloon was inflated. After placing the patient in the supine position, the infusion system was opened and the saline solution filled the colon retrogradely by gravity. During the study, the patients were turned on their sides to distend poorly repleted areas. In HSEC, the echographic contrast agent was injected intravenously after completing the retrograde instillation of the saline solution and after the localization of the lesion. No antispasmodics or sedation was used.

The ultrasounds were performed by a single abdominal ultrasound specialist using a low frequency convex probe. The lesions were studied by a pathologist and classified by size into three categories: smaller than or equal to 5 mm, 6-10 mm, and larger than 10 mm. The reference size of the lesion was the major axis measured by the colonoscopist or by the pathologist in surgical cases. The results of the HS were compared with those of the OC. In the case of stenosing lesions, since patients required a CT-colonography, the results of the echography and the CT-colonography were compared to with the results of the control OC after surgery. In addition, when HSEC was carried out, the location of the lesion was marked on the skin with a permanent marker.

Sensitivity and specificity were calculated from the rectum-sigma junction to the cecum, excluding the rectum. Sensitivity was calculated using the total number of lesions in each size category and specificity using the number of patients who had a negative OC in each size category. Statistical analysis was performed using analysis of variance (ANOVA).

4. Results

Of the 73 ultrasounds, in one HSEC patient (1.4%), complete distension of the colon from the rectal ampulla to the cecum was not possible, due to an 8 cm stenosing lesion in the transverse colon. With the exception of another HSEC (1.4%) due to a stenosing neoplasm of 40 mm sigma, all patients tolerated the full scan.

The OC detected 178 lesions but only 175 were included in the histological study, since two polyps of 3 and 7 mm could not be recovered and another of 5 mm had artefacts that prevented their assessment. In addition, four lesions of between 2 and 5 mm had inflammatory changes and two lesions of 3 and 4 mm corresponded to healthy mucosa. In the remaining 169 lesions we observed 40 hyperplastic polyps, 86 low-grade dysplasias, 22 high-grade dysplasias and 21 adenocarcinomas including those in situ (Tables 1 and 2). Our data showed a direct relationship between lesion size and the degree of histological severity ($p < 0.05$) (Figure 1) (Tables 1 and 2). No significant differences were observed between hyperplastic lesions and low-grade dysplasias, although both groups differed from high-grade dysplasias and adenocarcinomas ($p < 0.05$) (Figure 1).

The sonographer detected 84 lesions, with a total of 4 false positives (haustra falsely classified as lesions of 11, 11, 10 and 9 mm). In lesions exceeding 10 mm, the sensitivity was 93% and the specificity was 95.1% (Table 3). The OC detected 45 lesions while the sonographer described 42 lesions, with 2 false positives. Of the 5 lesions not detected by HS, two of them were in the rectum and the other was a flat lesion. In the lesions measuring 6-10 mm, the sensitivity obtained was 70 % and the specificity was 96.1 % (Table 3). The HS detected 28 lesions with 2 false positives, while the OC detected 39. In the case of the 13 undetected lesions, 2 were in the rectum and another was a flat lesion. In lesions smaller or equal to 5 mm, the sensitivity was 15.9% and the specificity was 100% (Table 3). HS detected 14 lesions, compared with the 94 detected by OC. In this size range, too, 11 flat lesions and 6 rectal lesions were not detected. In the case of adenocarcinomas, sensitivity and specificity was 100%.

In one HS (1.5%), the sonographer judged the preparation to be poor, but the colonoscopist considered it optimal. This patient presented 12 lesions: nine polyps of 0-5 mm, one of 8 mm and two of 15mm. None was detected by HS. On two occasions, the colonoscopist considered the preparation poor, while the sonographer considered it optimal. In the first case, the sonographer did not see any lesions, but in a second OC two polyps of 5 and 7 mm were detected. In the second case, two OC were performed, in the first of which, a stenosing lesion of 40 mm and four anterior lesions of 20,8,7 and 4

mm were detected. In the second OC, the stenosing lesion could not be crossed. In the HS, a stenosing lesion of 40 mm and five previous lesions of 27, 21, 20, 19 and 10 mm were observed, which were confirmed by intraoperative OC.

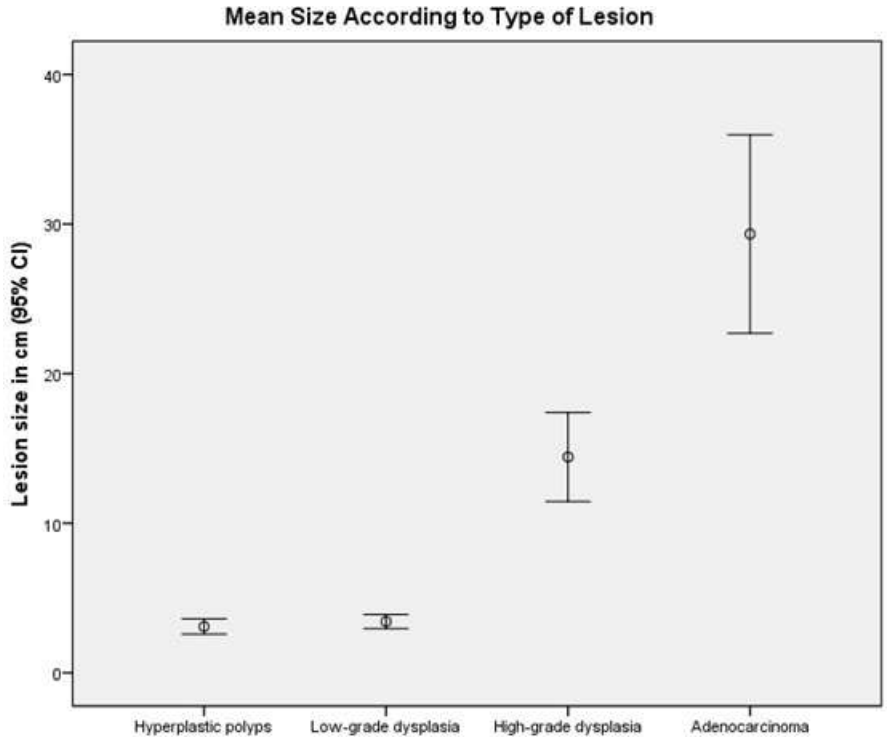

Figure 1: Mean size of lesions according to histological grade

Table 1: Number of lesions arranged by size interval, according to histological grade and stage

Histological grade /Stage	Number of lesions ≤ 5 mm	Number of lesions (6-10) mm	Number of lesions >10 mm
Hyperplastic polyps	34	5	1
Low-grade dysplasias	53	28	5
High-grade dysplasias	1	5	16
In situ Adenocarcinoma	0	0	12
T1 Adenocarcinoma	0	0	1
T2 Adenocarcinoma	0	0	1
T3 Adenocarcinoma	0	0	6
T4 Adenocarcinoma	0	0	1
In situ adenocarcinoma: Tumour in the mucosa. T1 adenocarcinoma: Invasion of the submucosa. T2 adenocarcinoma: Invasion of the muscularis propria. T3 adenocarcinoma: Invasion of the serosa. T4 adenocarcinoma: invasion of other organs or structures.			

Table 2: Histological grade, number of lesions and size.

Histological grade /Stage	Number of lesions	Average size (mm)	Range (mm)
Hyperplastic polyps	40	3,73	1-18
Low-grade dysplasias	86	5,8	2-45
High-grade dysplasias	22	14,32	5-30
In situ Adenocarcinoma	12	23,75	13-40
T1 Adenocarcinoma	1	40	
T2 Adenocarcinoma	1	35	
T3 Adenocarcinoma	6	30,17	19-40
T4 Adenocarcinoma	1	80	
In situ adenocarcinoma: Tumour in the mucosa. T1 adenocarcinoma: Invasion of the submucosa. T2 adenocarcinoma: Invasion of the muscularis propria. T3 adenocarcinoma: Invasion of the serosa. T4 adenocarcinoma: invasion of other organs or structures.			

Table 3: Sensitivity and specificity (HS)

Size	Sensitivity	Specificity
≤ 5 mm	15,9 %	100%
6-10 mm	70%	96,1 %
>10 mm	93%	95,1 %

Regarding the results of the HSEC (Table 4). In the 8 HSEC performed all the lesions were enhanced, enabling 9 lesions to be observed, 7 adenocarcinomas, 1 high-grade dysplasia and 1 low-grade dysplasia. In one case, complete repletion of the colon was not achieved. In our study, where no cleaning preparation was used, faecal debris was the main cause of poor visualization. Faecal remains produced suboptimal acoustic windows, due to adherence to the colonic wall or accumulation in the colonic lumen. Therefore, within the case of HS, lesions were only totally observed faecal matter did not produce suboptimal acoustic windows. However, with HSEC all lesions were fully visualised, except on one occasion. Although lesion enhancement allowed clear differentiation from faecal debris, on four occasions the presence of faecal matter made it impossible to determine the total lesion enhancement time. On one occasion, discomfort forced a premature ending to of the procedure. The pre-surgical location of the 9 lesions was correct with and without the application of an echographic contrast agent.

Table 4: Findings in HSEC

Histological grade and stage	Size and localization	Acoustic window	Enhancement time	Limiting factor
Low-grade dysplasia	45 mm Cecum	Suboptimal	Not determined	Faecal remains
High-grade dysplasia	20 mm Descending	Optimal	100 sec.	No
In situ adenocarcinoma	18 mm Transverse	Suboptimal	Not determined	Faecal remains
In situ adenocarcinoma	36 mm Sigma	Optimal	330 sec.	No
T3 adenocarcinoma	19 mm Rectum-sigma	Suboptimal	Not determined	Faecal remains
T3 adenocarcinoma	35 mm Descending	Optimal	100 sec.	No
T3 adenocarcinoma	40 mm Sigma	Suboptimal	120 sec.	Faecal remains
T3 adenocarcinoma	40 mm Sigma	Suboptimal	Incomplete 140 sec.	Faecal remains Discomfort
T4 adenocarcinoma	80 mm Transverse	Suboptimal	Not determined	Faecal remains Distension
In situ adenocarcinoma: Tumour in the mucosa. T1 adenocarcinoma: Invasion of the submucosa. T2 adenocarcinoma: Invasion of the muscularis propria. T3 adenocarcinoma: Invasion of the serosa. T4 adenocarcinoma: invasion of other organs or structures.				

Of the 21 adenocarcinomas, five were stenosing (the OC was unable to study proximal segments to the lesion). In our study, there were ten proximal lesions undergoing stenosis, and HS detected all lesions of 10 mm or more. Lesions between 3 and 5 mm proximal to the stenosis were not detected by HS or by CT-colonography. On three occasions HS and CT-colonography did not detect lesions prior to the stenosis, but in the control OC after surgery, five small lesions between 3 and 5mm were detected, in one patient, none of which had been described by HS or CT- colonography. In one case, CT-colonography was not performed, as HS detected five lesions between 10 and 27 mm, which were confirmed by intraoperative OC. Of these lesions, the largest corresponded to a malignant polyp (adenocarcinoma in situ). Finally, in an 80 mm adenocarcinoma located in the transverse colon, the enema did not cross the stenosis and proximal sections could not be studied with HS or using CT-colonography. In the same patient an HSEC was performed and no lesions were observed, findings which were confirmed in the control OC after surgery.

5. Discussion

In our study, HS sensitivity for small lesions was low, but improved in the case of larger lesions (Table 3). This relation, directly proportional between sensitivity and size, has been observed in previous studies, in which lesions smaller than 7 mm sensitivity ranged between 0 [3] and 5% [5], while in lesions equal to or greater than 7 mm a sensitivity of 12,5 % has been mentioned [6], although most range between 50 and 91% [2,3,5]. In adenocarcinomas, which are bigger lesions (Table 1 and 2), sensitivity was higher between 70.6 and 100% [2-5, 7-11]. In our study it sensitivity was 100 %.

In a CT-conolography meta-analysis, Mulhall [13] reported a sensitivity of 21-70% for polyps less than 6 mm, 55-84% for polyps between 6 and 9 mm and 48-100% in polyps greater than 10 mm. Comparing the sensitivity of HS and CT-colonography, the sensitivity of HS for small lesions is lower than the sensitivity of CT-colonography. However, in our study, these small lesions showed a low histological degree (Tables 1 and 2). We only observed one high degree dysplasia in a polyp of 5 mm (Table 1) and the smallest adenocarcinoma was 13 mm (Table 2). Although characteristics such as a villous or tubulovillois histology, left-side location and age ≥ 60 are independient risk factors for advanced pathological features in colorectal adenomas, adenoma size is the most important factor for advanced pathological features [14]. There is a direct relation between lesion size and risk of cancer [15-17]. In those measuring 0-5 mm, the risk of invasive

growth is 0-0.1%, which increases to 0-0.4 % in lesions measuring 6-9 mm [15] and then gradually increases to 19.4% in polyps measuring more than 20 mm [16]. In a study by CT- colonography, while not reporting any lesions of less than 6 mm, Kim [18], obtained an incidence of 0.2 cancers per 1000 patients/year when realizing a follow up study years later.

HS exhibits the typical limitations of ultrasound such as those related with obsesity [3,6], poor acoustic window [3], the presence of gas [3, 5] or high operator dependency. Furthermore, the presence of faecal remains [3, 5], the existence of anatomical variants such as the redundancy of sigmoid colon [5], the existence of poorly repleted areas or the disposition of the transverse colon make the study difficult. HS requires toleration to repletion and although it is possible to decrease the volume of saline solution that is introduced, incomplete studies may result [3, 6]. Complications such as vasovagal episodes and diaphoresis have also been reported [6].

With the data obtained, HS cannot be considered a suitable technique for studying the rectum, since, as other authors have also found [6, 19, 20], our results were poor. The lower portion of the rectum was not visible [7], since the colon was distended from the rectal ampulla. Furthermore, the presence of the balloon in the ampulla produces poor visualization [5]. Other factors such as pubic symphysis [3, 8] and its depth [3] also make it difficult to visualize. Thus, most of the studies carried out inclusively cover the zone from the rectum-sigma junction to the cecum [2-5, 9].

In advanced stages, adenocarcinomas usually present a thickening of the wall with irregular morphology that narrows the lumen of the colon (Figure 2 and 3). However, adenocarcinomas can also appear in lesions of polypoid morphology (Figure 4 and 5). Although this usually occurs in large polyps, it is not always easy to differentiate polyps from haustra. Haustra of the colon [5, 12] (Figure 5,6 and 7) and polyps [2, 3], appear as hyperechoic structures projected into the colon lumen. Polyps differ from haustra in their morphology (sessile, pedunculated or semi-pedunculated) (Figure 4, 5, 6,7, 8 and 9) and by their behavior. Thus, they tend to move in the colon lumen during retrograde instillation [2, 4], with external compression [2, 4] or when the patient turns [12], since they are less rigid and more mobile than the haustra. However, in flat lesions which have minimal or no relief [21], these criteria are not applicable. In our study, flat lesions were not detected because the complexity involved: first, due to the variability in wall thickness, which ranges from 3 to 4 mm [19,22], but may frequently reach 5 mm in the sigmoid colon due to the hypertrophy of the muscular is propria [19]: and secondly, it is not possible to use linear transducers, which are more suitable for small details, in deep regions due to their lower penetration. Finally, faecal remains need to be kept to a minimum.

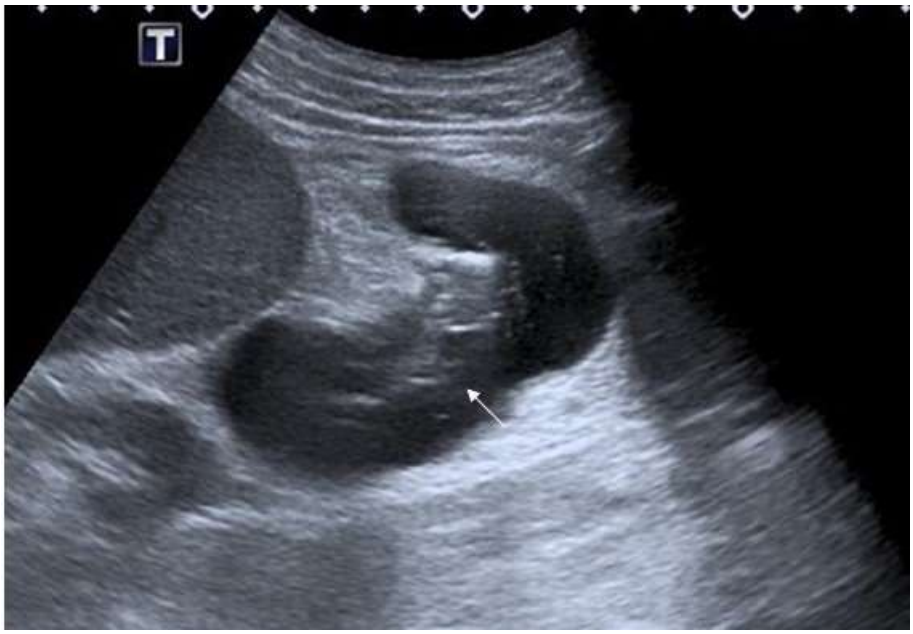

Figure 2: Adenocarcinoma

Heterogeneous mass of 36 mm located at a splenic angle (thin arrow), diagnosed as adenocarcinoma with invasion of the serosa

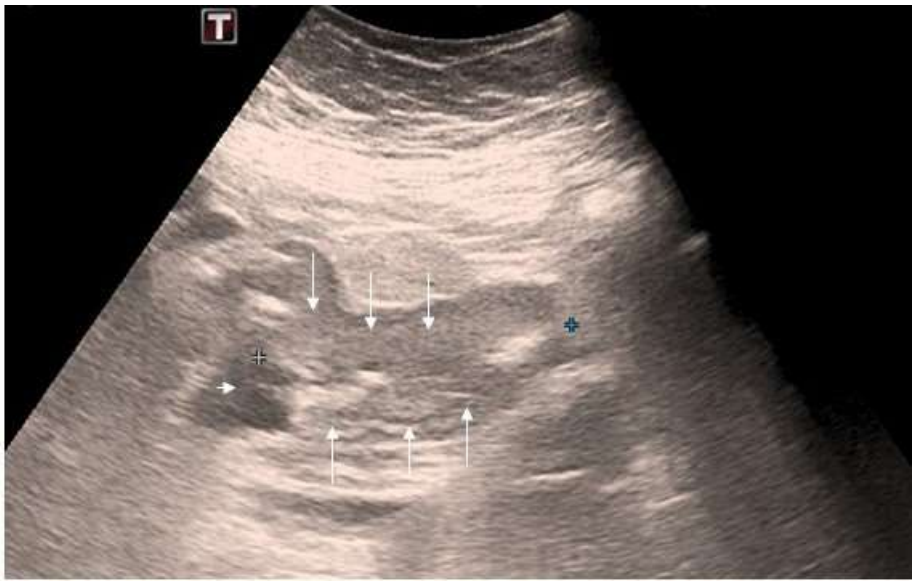

Figure 3: Adenocarcinoma located in the sigmoid colon

Segment of sigmoid colon with an adenocarcinoma of 30 mm. Among the marks, the ends of an unreplenished area. Hypoechoic thickening of the colon walls (thin arrows). To the left of the image but lower than the tumor, the saline solution that distends the sigmoid colon (short arrow) can be observed.

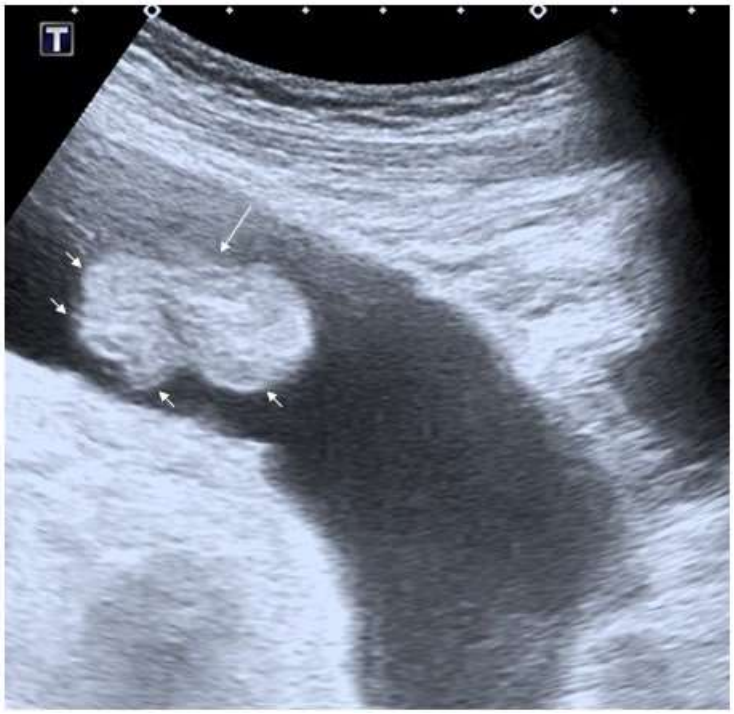

Figure 4: Multilobulated polyp with diagnosis of adenocarcinoma

Polyp of 33 mm (thin arrow) with pathological diagnosis of adenocarcinoma in situ, and its lobulations (short arrows).

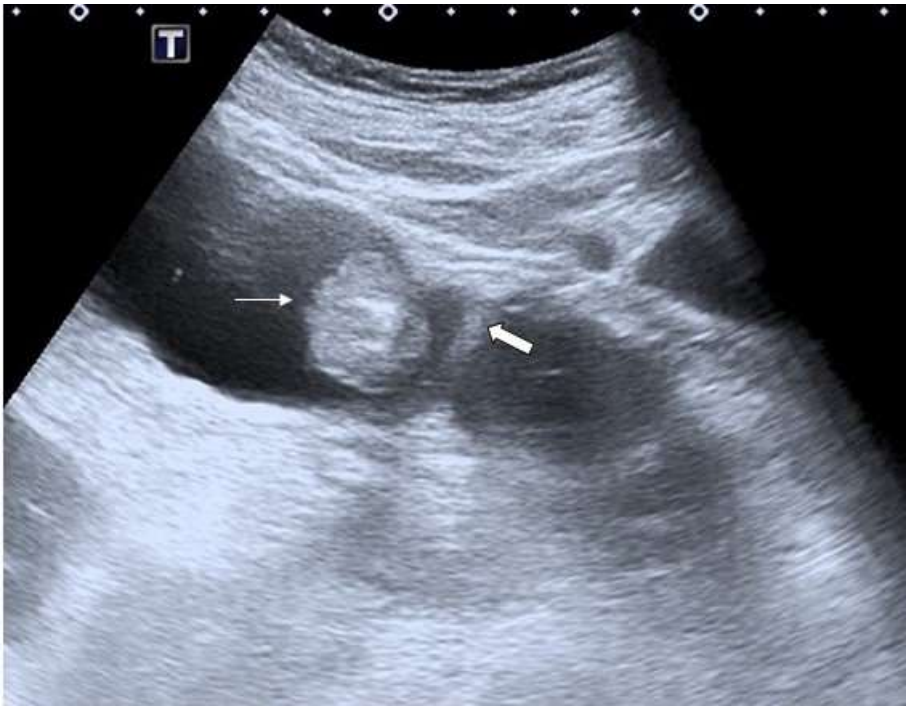

Figure 5: Sessile polyp with diagnosis of adenocarcinoma

Polyp of 23 mm (thin arrow) with pathological diagnosis of adenocarcinoma in situ. Adjacent to the lesion, a haustrum (thick arrow) can be observed.

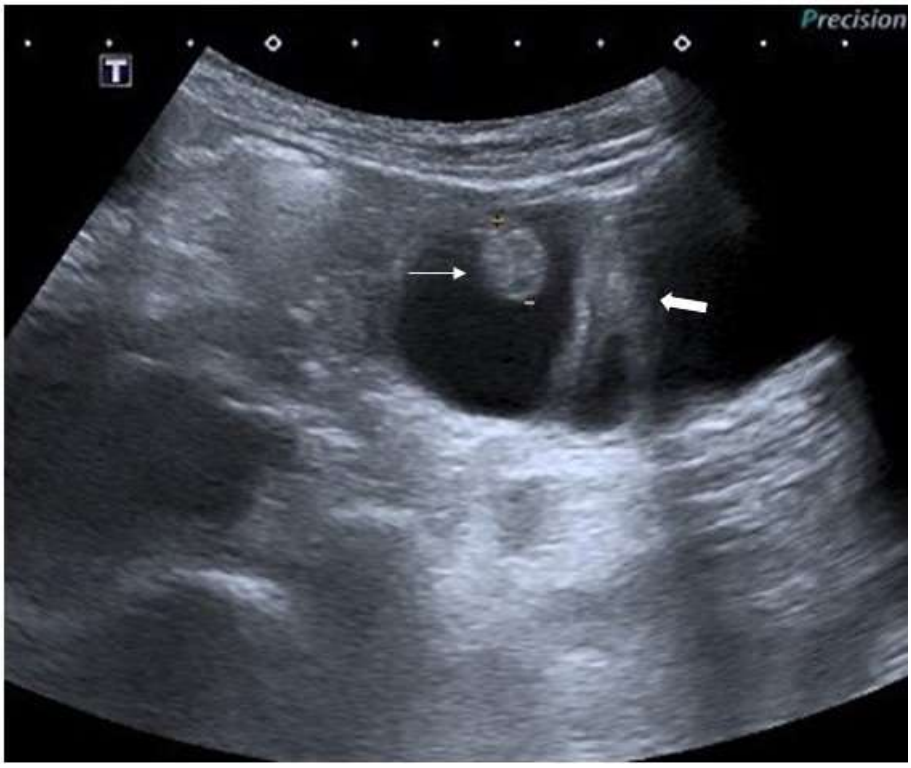

Figure 6: Sessile polyp

Sessile polyp of 12 mm (thin arrow), with pathological diagnosis of high-grade dysplasia. Haustra of the colon (thick arrow).

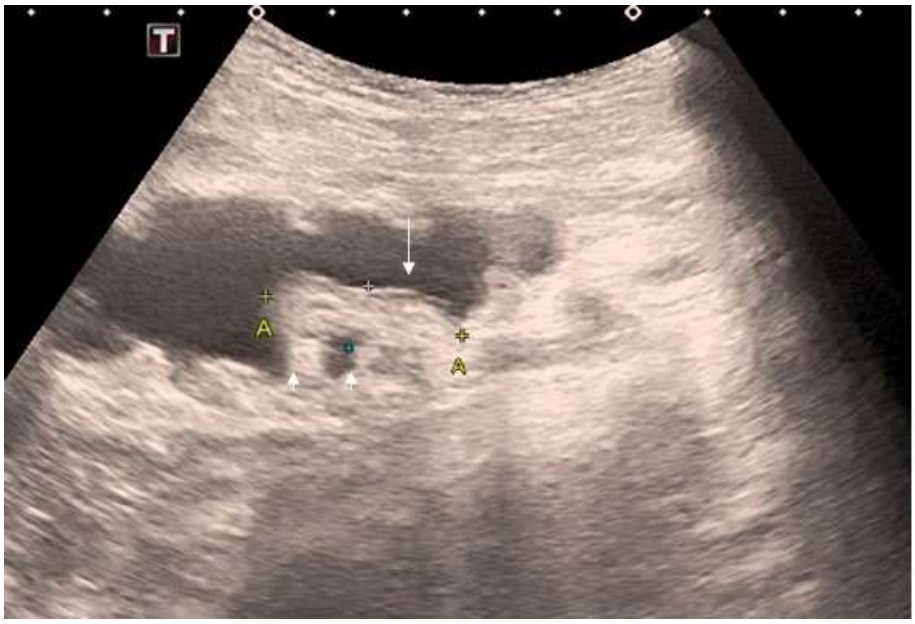

Figure 7: Pedunculated polyp

Among the marks is a pedunculated polyp, with a thick peduncle (thin arrow). The polyp is 26 mm long and is located in the sigmoid colon. Colonic haustra (short arrows).

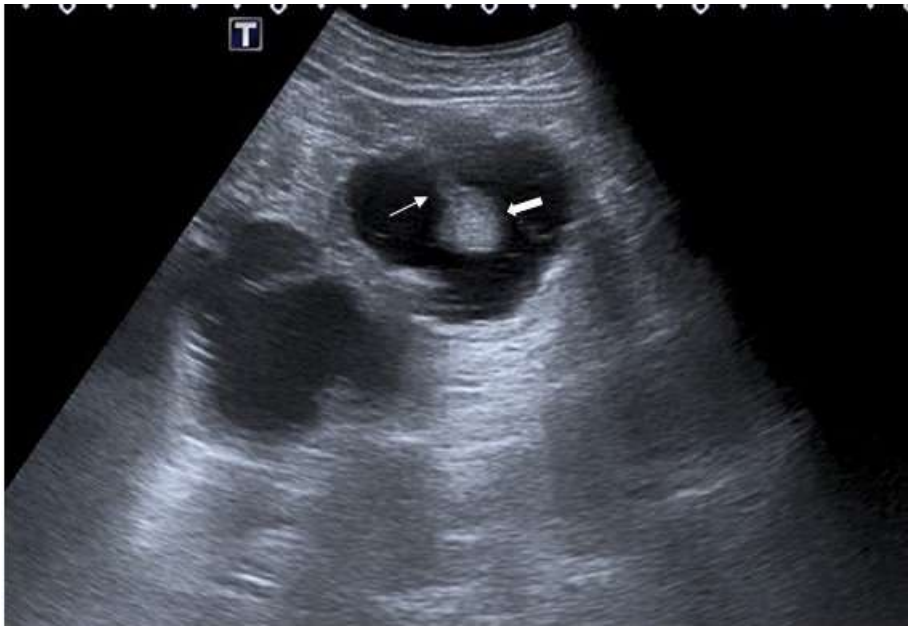

Figure 8: Pedunculated polyp with thin peduncle.

Pedunculated polyp of 12 mm. In the colonic lumen, the head of the polyp (thick arrow) and the peduncle (thin arrow) that connects it to the colon wall are visible. This polyp located at liver angle was anterior to the stenosing mass of figure 2.

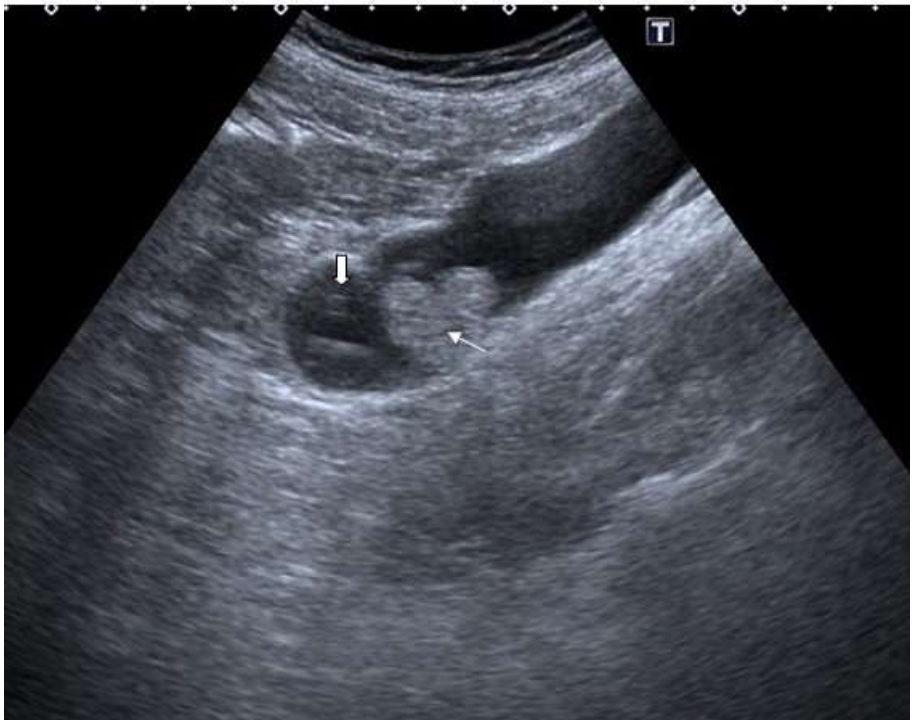

Figure 9: Lobulated polyp
Lobulated polyp (thin arrow) and faecal remains (thick arrow).

Faecal remains, which usually accumulate in the right colon [5, 12], produce incomplete studies [3] and are the main cause of poor visualization [5]. The faecal remains can be observed as they move using the transducer to compress the abdomen quickly and lightly [2, 4, 12], during retrograde instillation or when the patient is turned. To improve the visualization of the colon wall, it is recommended that a higher volume of saline solution be infused [12]. This process decreases the concentration of faecal remains but is not always possible due to the patient's tolerance level to repletion. In these cases, lowering the saline solution bag until the colon is empty and then placing another bag to perform a new retrograde instillation is a simple way to decrease the concentration of faecal remains without having to resort to a new rectal probe.

In HSEC (Table 4), faecal remains were abundant since no cleaning preparation was used. HSEC is a useful tool for differentiating lesions from faecal remains, as the latter are not enhanced (videos 1 and 2). However, the presence of faecal matter made it impossible to determine the complete enhancement time on four occasions. As long as the lesion is very enhanced it is easily distinguishable from faecal matter, but enhancement gradually diminishes until the lesion in no longer distinguishable from faecal matter, which prevents the determination of complete enhancement time. A limitation of the echographic contrast agent is the enhancement time, understood as the time in which the enhancement of the lesion permits it to be clearly defined. Although its determination may suffer from subjectivity, the time reached a maximum of 330 sec. in our study, which is much lower than the average time taken by HS (between 13.7 and 30 minutes) [2-7, 9, 12]. Although very few patients have been studied by HSEC, this limited time represents a handicap for studying extensive regions and its use is better suited to local or poorly repleted zones, such as flexures (Figure 10), sigmoid colon (video 1) or narrowing's of the colonic lumen (video 2).

HS can also be used as a tumour marking technique. Normally, marking the lesion with ink made by OC is sufficient for its to be located during surgery. However, the dyes injected during OC can migrate from the lesion or fail to show [23], sometimes making it necessary to perform another OC to make a new mark. Although intraoperative HS has been used to locate these lesions [24-26], its preoperative performance is less complex. In our study, the pre-surgical location of the nine lesions was correct with and without the application of an echographic contrast agent. Pre-surgical marking of the lesion is performed on the skin with the patient lying supine, but the retrograde instillation has to be slow, suspending the infusion if the filling process cannot be followed visually, since it is necessary to detect anatomical variants such as sigma redundancy or transverse arrangement which can cause localization errors. Pre-surgical localization is not a widely used technique, but it can be helpful for small lesions, partially resected lesions or in bordering locations, which may lead to changing the surgical technique to be used.

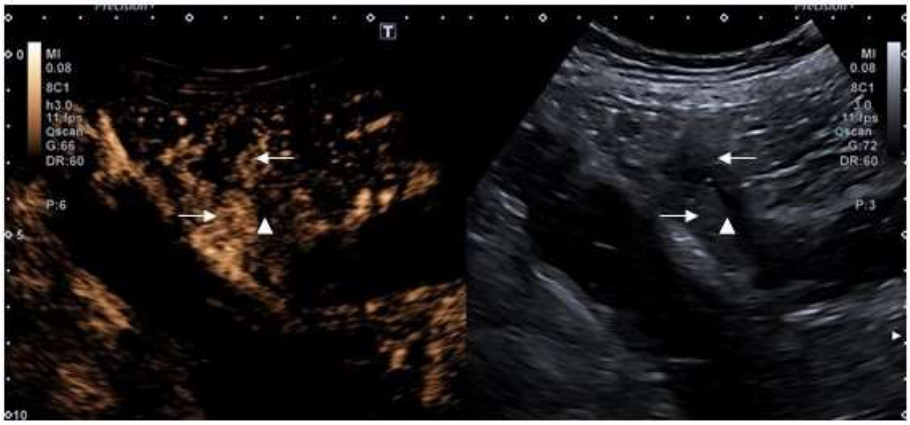

Figure 10: Dual image of stenosing adenocarcinoma

Dual image of stenosing adenocarcinoma in the splenic angle, with ultrasound contrast in the left half and with no contrast in the right half. The thickened wall is highlighted on the left half and the hypoechoic thickening on the right half (thin arrows). In both images, the filiform passage of the serum (arrowheads) can be observed, appearing in the form of an "inverted apple core" in the left half of the image.

Although CT-colonography is the gold-standard in the case of incomplete colonoscopies for stenosing neoplasms, HS/HSEC is an option without radiation that can offer good results. In our study, with few stenosing lesions, the HS data for the detection of lesions proximal to the stenosis appear to be similar to the data obtained in an examination in which no stenosis exists, that is, high sensitivity in lesions of 10 mm or more and low in lesions less than or equal to 5 mm. However, these small lesions (smaller than or equal to 5 mm) have a lower risk of presenting severe histological changes (Figure 1) (Tables 1 and 2). On one occasion, the stenosis prevented the assessment of the proximal colonic sections, which was not possible using HS or CT-colonography. Although, in our study, this occurred with a large 80 mm lesion in stage T4, the impossibility of distending segments proximal to the lesion using HS is already known [5]. To study the sections proximal to this large lesion, the echographic contrast agent (HSEC) technique was used, however, although this may be helpful for adequate visualization, it is necessary to achieve distension of the area to be studied.

6. Conclusions

The sensitivity of hydrocolonic sonography increases progressively with the size of the lesion and, although it is low in the case of small lesions, these are normally of low histological severity and present a lower risk of adenocarcinoma. HS has a sensitivity comparable to CT-colonography in lesions greater than or equal to 6 mm but lower in lesions of less than or equal to 5 mm. HS is not a suitable technique for studying the rectum, or flat lesions. The application of an echographic contrast agent (HSEC) produces an improvement in visualization, especially when there are faecal remains or poorly repleted areas. HS/HSEC can offer good results for the detection of proximal lesions to the stenosis mass.

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