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ORIGINAL ARTICLE

Virtual colonoscopy: Technical guide to avoid traps and pitfalls

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KEYWORDS

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High risk patients;
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2D navigation;
3D navigation.

Abstract The study aims to clarify the ideal technique of virtual colonoscopy and how to avoid pitfalls.

Patient and methods: 200 patients were referred for VC screening.

Results: 3D VC false positive results were as follows: Pseudopolyps due to fecal residue (17.5%), under-distended colon (2%), segmental spasm (1%), respiratory motion artifacts (3%), prominent colonic haustrations (8.5%), prominent ileocecal valve (4.5%), prominent appendicular stump (0.5%) and false pits due to shine-through (1.5%). 3D false negative results were proved secondary to fecal residue (1.5%), retained fluid (2.5%), colonic under-distention (5%), prominent colonic folds (1%) and sessile polyps (1%).

2D navigation: There were no false positive results. 3.5% false negative results were due to different combinations of fecal residue (3%), fluid (2%), under-distended colon (1%), prominent colonic haustrations (2.5%) and sessile polyps (1%). Finally, true positive results were proven in 40% of 3D and 47.5% of 2D navigations, true negative: 29.5% in 3D and 49% 2D. False positive results were proven in 19.5% of 3D, false negative results: 11% 3D and 3.5% 2D. 3D 78.4%, 2D 93% sensitivity and 3D 60.2% & 2D 100% specificity records.

Abbreviations: AGH, Al-Mana General Hospital; CO_2, carbon dioxide; C-RADS, CT Colonography Reporting and Data System; CT, computed tomography; MSCT, Multislice CT scan; ROI, Region of interest; SSD, shaded-surface-display; VC, virtual colonoscopy; 2D, two dimensions; 3D, three dimensions.

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Conclusion: Many overestimating or underestimating VC pitfalls could be avoided, through mastering the technique and being more familiar with different navigation methods and these technical pitfalls.

1. Introduction

Colorectal malignancy is the third (after lung and breast) leading cause of deaths from neoplastic diseases, worldwide. In the United States, it has similar records if men and women are estimated separately; however it is the second leading cause if estimation for both sexes is done in combination. 150,000 is the average annual record of newly diagnosed cases in USA, which caused 56,000 deaths in 2005, being the second highest record of deaths from malignancy. Also, the lifetime risk factor to develop colon cancer is 6% and lifetime risk factor to die from colon cancer is 2.5%. The incidences of colorectal cancer in the Arab world are relatively low, considering indices of patients older than 40y; however, there are some upcoming higher scores as regards patients of younger age groups (1–4).

Colorectal carcinoma can be described as preventable disease, as there are many precancerous colonic diseases e.g. colonic polyposis. If these precancerous polyps were early detected and controlled, this will significantly reduce colon cancer morbidity and mortality incidences. The known premalignant

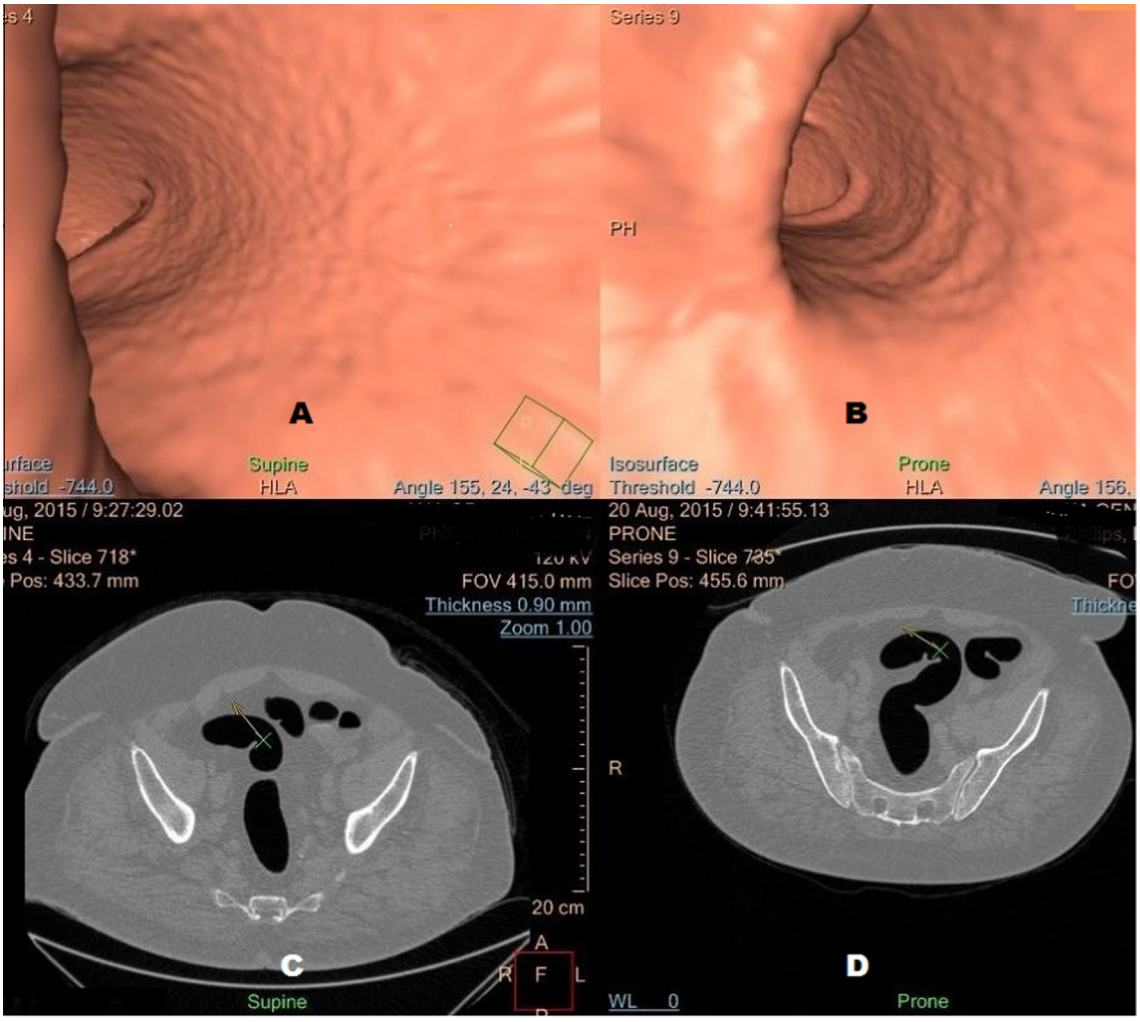


Fig. 1 Comparative 3D virtual colonoscopy navigation images at the same site of the sigmoid colon in supine (A) & prone (B) positions with corresponding 2D supine (C) and prone (D) images.

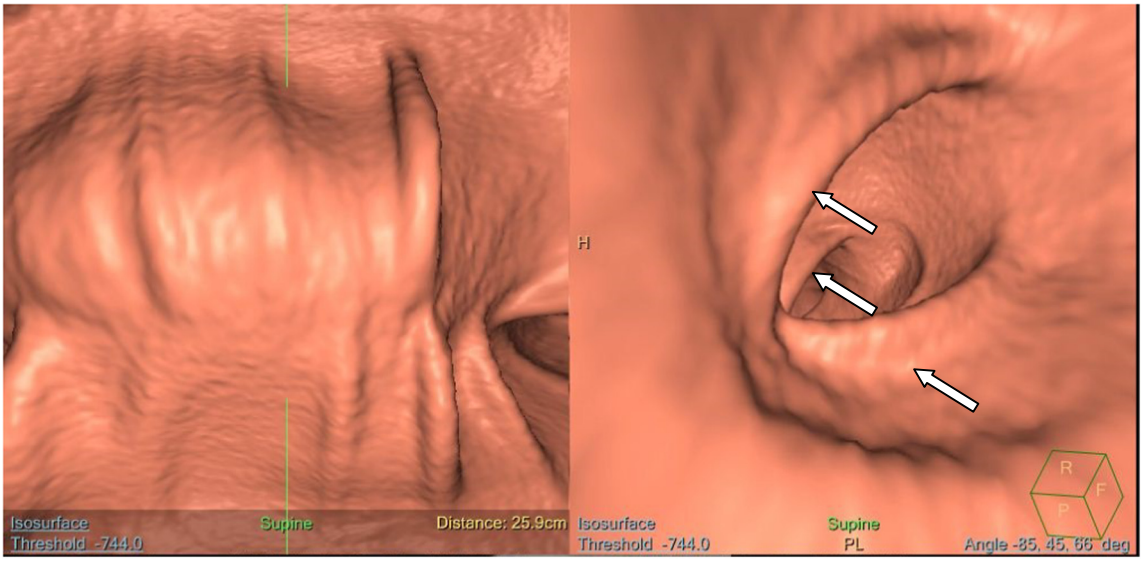


Fig. 2 Usage of filet image (A) in correspondence with the VC navigation view (B) which dissects the lumen, for clear demonstration of the colonic inner surface beyond the thick folds (Arrows in B) that may mask small lesions.

Table 1 Summary of CT Colonography Reporting and Data System: Colorectal and Extracolonic Classification Scores.

Findings	Description	Conclusion	Recommendation
Colorectal			
C0	Inadequate preparation or insufflation	Inadequate study	To be repeated
C1	No polyp $\geqslant$ 6 mm	Unremarkable study	Routine screening
C2	Polyps 6–9 mm, $<$3 in number	Indeterminate findings	Polypectomy
C3	Polyps $\geqslant$10 mm; $\geqslant$3 polyps	Possibly advanced adenoma	Polypectomy
C4	Infiltrating colonic mass	Colorectal malignancy	Surgical consultation
Extracolonic			
E1	Normal	Normal examination	No workup indicated
E2	Simple findings: e.g. simple liver or renal cyst	Unimportant finding	No workup indicated
E3	Minimally complex e.g. Bosniak II Renal cyst	Likely unimportant	Remarks for physician
E4	Some serious findings e.g. aortic aneurysm extracolonic mass	Potentially important	Contact physician

colonic polyps usually change histopathologically from adenoma, to dysplasia, to carcinoma, within a period of 10–15 years. This is why screening methods for early detection and treatment of precancerous polyps are considered lifesaving tools. At autopsy, 60% of men and 40% of women had been proved to get colonic polyposis (5,6).

Screening programs aiming to detect and remove polyps more than 1 cm in size, can yield 50% reduction of mortality. These programs include annual stool analysis for occult blood, which may notify for bleeding polyps. Regardless, it is cheap affordable tool; it is of poor sensitivity and specificity. Also, barium enema may be used as annual screening tool; however, it is less sensitive for small polypoidal growth. Flexible sigmoidoscopy is safe procedure with no need for anesthesia during its application; however, it can only cover 50% of the colon. Colonoscopy is undoubtedly very sensitive screening tool, and also removal of the polyps could be done if found during the process; however, there are some limitations for its frequent application (7–10).

Computed tomographic colonic navigation was first introduced by David Viningin 1994, as imaging method for the interior surface of the colon. With the aid of some new software programs, 3D endoluminal view could be obtained, hence the name virtual colonoscopy (VC). After introduction of the multidetector CT scan, this screening tool of imaging had become very sensitive tool for diagnosis of small colonic polypoidal lesions. The sensitivity and specificity of VC in diagnosing polyps larger than 1 cm- as published in some researches- may reach 97% and 100% respectively. However, these figures may be reduced to 86% for polyps less than 10 mm. Despite this reduction in sensitivity for smaller sized polyps, it is not clinically troublesome as the risk of malignancy in a polyp less than 1 cm in size is less than 1% (11–13).

Advances of VC over colonoscopy are its shorter scanning time, being less invasive with lower morbidity scores, less coasty and better tolerated by the patients. Despite its high sensitivity, there is a still recorded false positive result, that may lead to unnecessary invasive colonoscopy or even unnecessary biopsy procedures. This is why the reporting radiologist should be acquainted by the detailed technical steps of the pro-

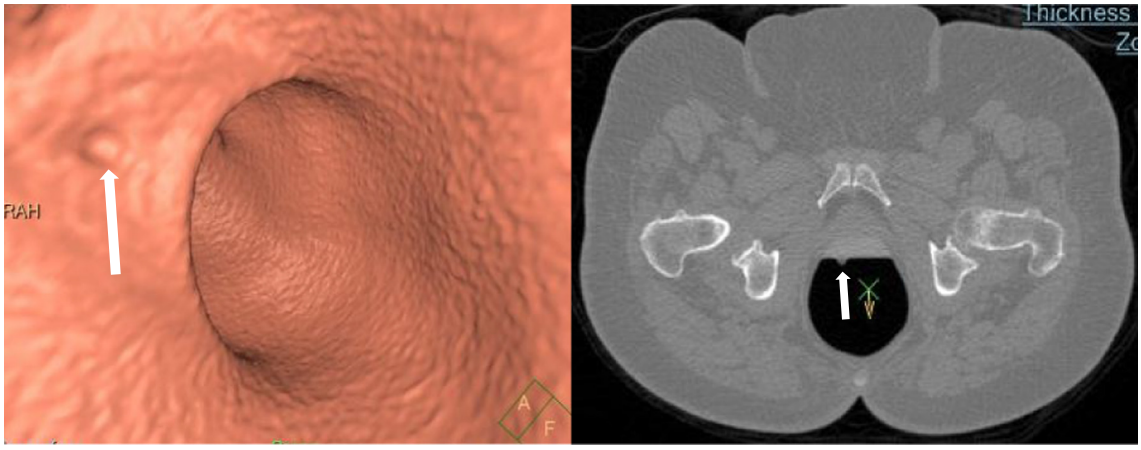


Fig. 3 3D VC navigation image shows small polypoidal like rectal projection (arrow), proven in corresponding 2D axial prone image (B) to be small fecal matter floating on some residual water (arrow).

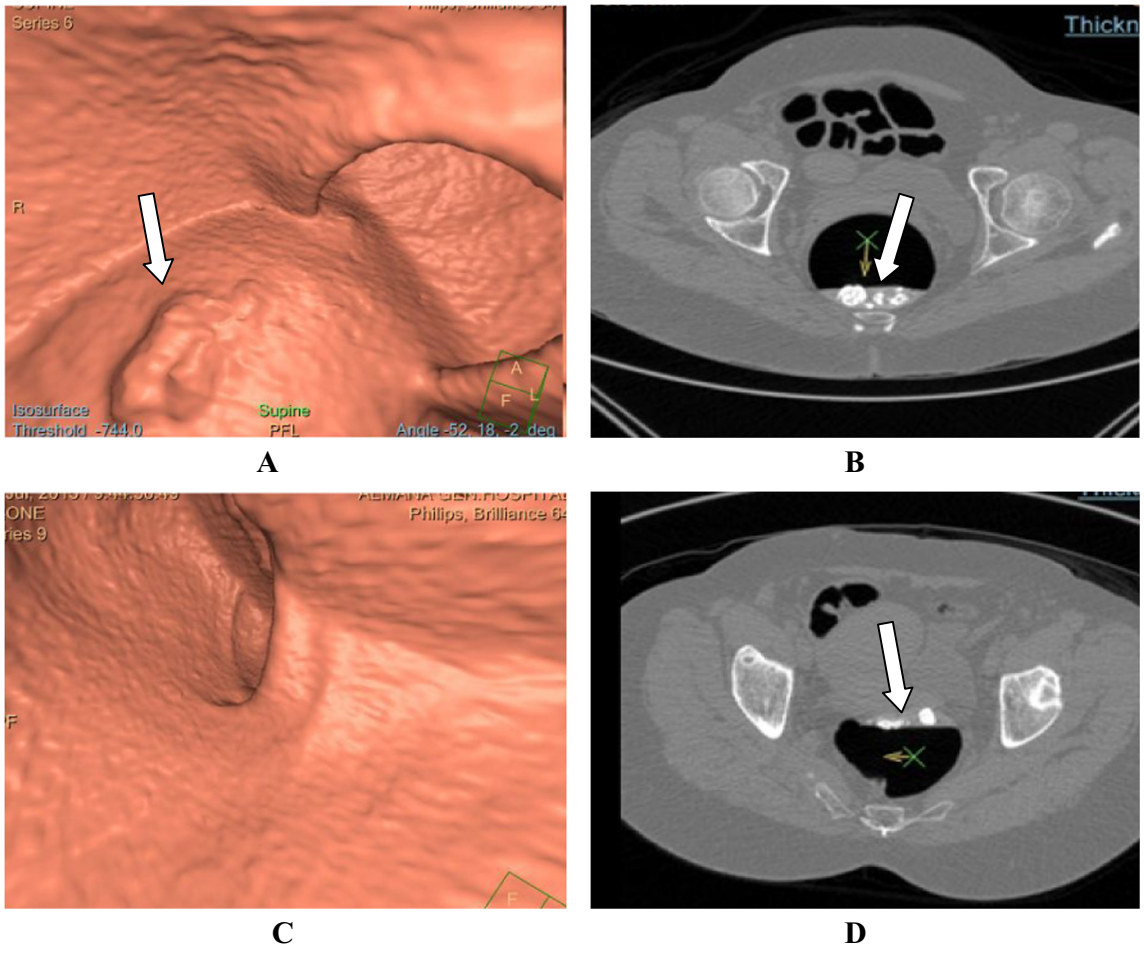


Fig. 4 (A and B) Supine position: irregular surfaced polypoidal like swelling is seen at the superior rectum, in 3D VC images (arrow in A), and it was proved to be barium tagged fecal matter floating in fluid in the corresponding 2D axial image (arrow in B). (C and D) Corresponding Prone position of the same position: the polyp is no more clearly seen in prone 3D VC navigation images (C), as it was spread, as seen in 2D image in (D) (arrow).

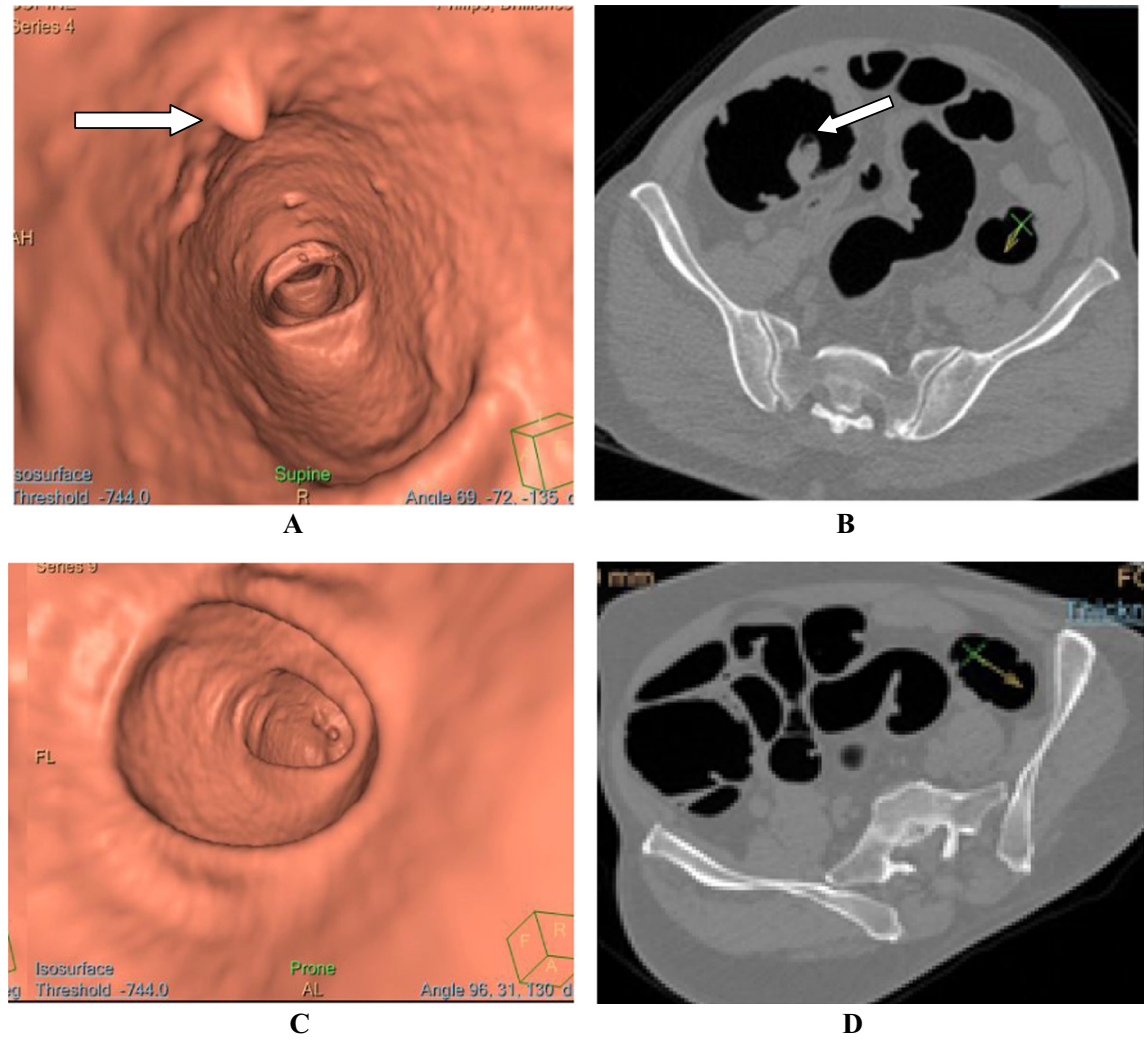


Fig. 5 (A and B) Supine position: Small ascending colon polypoidal like structure at 3D VC images (Arrow in A), clearly seen as gas containing stool particles in corresponding 2D axial image (Arrow in B). (C and D) Corresponding Prone position: Such fecal polypoidal like structure was displaced and no more seen at either 3D VC (C), or axial 2D images (D).

cedure to avoid pitfalls or misinterpretation of some normal variants (14–16).

2. Aim of the study

The study aims to clarify the perfect technique of virtual colonoscopy to avoid misinterpretation of frequently encountered traps and pitfalls that may occur secondary to technical errors. We thought that this task is considerably essential in practice, to avoid unnecessary invasive procedures for psuedolesions or missing of early diagnosis of potentially malignant lesions.

3. Patients and methods

3.1. Patients

Double blinded evaluation of virtual colonoscopic images of 200 patients, who were referred to radiology department of Al-Mana General Hospital (AGH), from January 2014 to August 2015, was done. Patients were referred for screening of high risk patients or due to unexplained bleeding per rectum. Besides the careful meticulous reporting of any positive findings, such as polyps, stricture or diverticula if present, record for false positive or negative signs was done in attempt to delineate all possible types of colonic pseudolesions, that may deceive VC unexperienced readers.

The study protocol was approved by the scientific and ethics committee in Al-Mana General Hospital (AGH). A signed consent was obtained from all study candidates, including detailed description of the technique with the rare possible drawbacks.

3.2. Technique (17)

Bowel cleansing instructions: (given to patients before examination for 24 h home preparation):

Picolax (Laxative): Picolax sachets should be taken 24 h before your appointment:

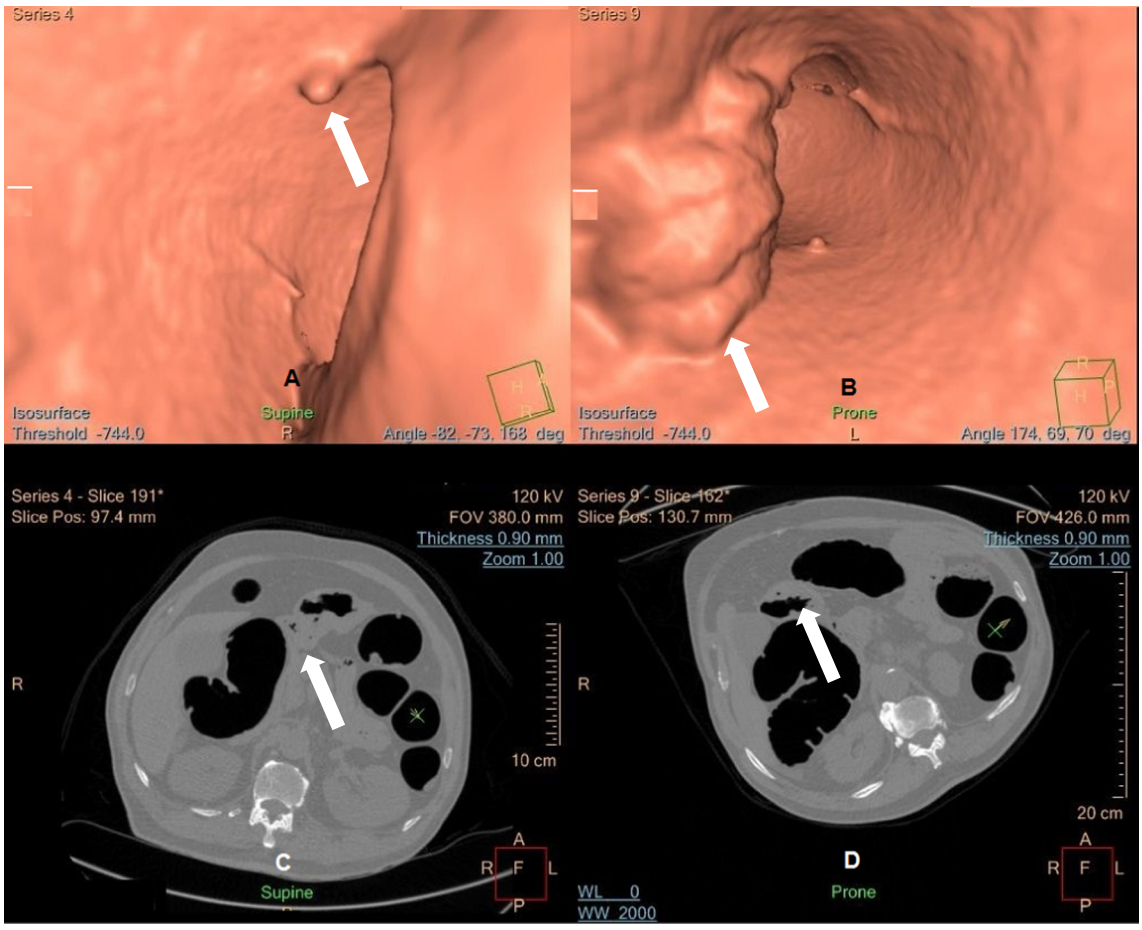


Fig. 6 Pseudopolyps due to under-distension and retained fluid: VC navigation images (A) supine, (B) prone & corresponding 2D images, (C) supine, (D) prone: showing collapsed lumen and small polypoidal like projection (Arrow in A), (large irregular shaped sessile polypoidal like projection (Arrow in B), corresponding to transverse colon under-distended segment with large amount of retained fluid), Arrow in C and D.

8.00 am (before breakfast) & at 3.00 pm (before lunch)

Dissolve Picolax sachet in a cup of cold water (150 ml), to be well mixed for 2–3 min before drinking.

3.3. Diet regimen (The day before your appointment)

Breakfast (8.00 am–9.00 am):

Eat one of the followings:

- 30 g cornflakes with 100 ml milk,
- 2 slices white bread/toast with a thin layer of butter and honey, or
- 1 boiled egg with 1 slice of white bread/toast, or
- 50 g cheese with 1 slice of white bread/toast.

Launch: (12–13.30 pm): Choose one of the following:
75 g of meat (e.g. lean, beef, lamb) or chicken or fish, or 2 boiled eggs.
And one of the following:

- 2 small (egg-sized) potatoes.
- 2 tablespoons plain white rice or pasta.

Mid-afternoon at 3.00 pm:
Take second Picolax sachet.
Dinner (7.00 pm–9.00 pm):
No solid food allowed.

- Clear soup made from chicken or meat extract cubes
- Clear jelly.

Important notice:

Drink plenty of water until diarrhea stopped, (at least 100 ml/h), to avoid dehydration and headaches.

900 ml of diluted barium preparation- formed of 225 ml of 4.9% barium sulfate sulfate suspension diluted by 675 ml water after dinner. At 12 pm, the last thing to be given is another similar dose of laxative. -Black tea/coffee can be taken if required

3.4. Insufflation

As a rule in VC, considerable colonic gaseous distension is a must before scanning, for clear visualization of all large bowel segments. After we did some trials for colonic insufflation with

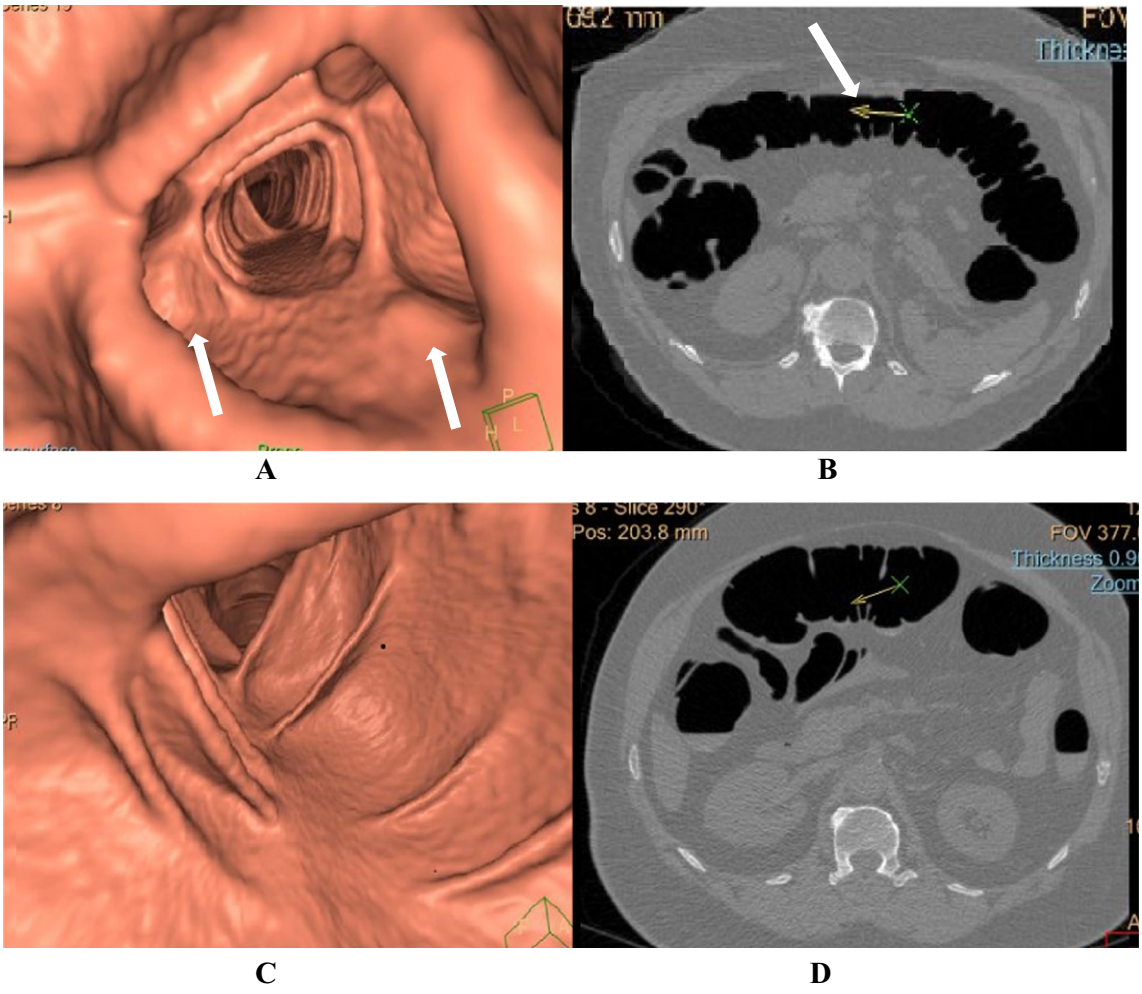


Fig. 7 (A) 3D VC supine image showing bilateral side walls sessile polypoidal like projections (Arrows) in transverse colon spastic segment seen in corresponding 2D axial image (B). (C) The same site prone VC image showing smooth side walls with no polyps, after spasm release, which is clearly seen in corresponding axial 2D prone image (D).

automated pump, we had preferred to use manual air insufflation for rapid adequate colonic distension. As for automated insufflation, it was recommended in more than one published literature to use Co2 not room air for ideal insufflation. Also, automated insufflation had been proven to take much longer time to achieve satisfactory colonic distension and may need repetitions (18).

3.5. Scanning

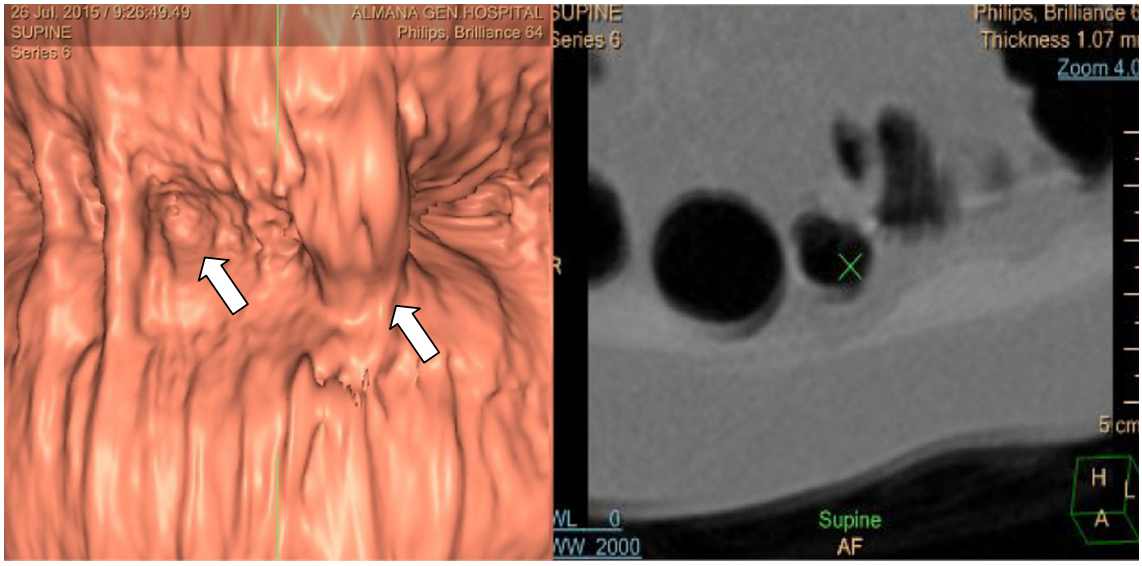
VC examinations were conducted on all study candidates using Philips Brilliance CT 64-slice, Philips Medical System, Nederland. B.V. Veenpulis 4–5, 4684 PC Best, The Netherlands. A preliminary scout was first done to assure satisfactory colonic distension. Then whole abdomen scans were acquired in both supine and the prone positions. Changing the patient's position helps to avoid misinterpretation of some mobile dependent fecal matters as pseudolesions like polyps (19). The advent of MSCT scan had enabled scanning large area in faster scanning time, so the whole abdomen could be scanned in single breath hold, with thinner collimation and minimal motion artifacts due to peristalsis (20).

3.6. Post-processing

After the end of 2D axial CT scan examinations in supine and prone positions, scanning data were sent to workstation for post processing 2D reformat and 3D flythrough navigation through different colonic segments, simultaneously as comparative study in both supine and prone positions (Fig. 1). Also second simultaneous navigation run was used to be done through both endoluminal 3D and the corresponding filet view, which dissects the colon and unfolds it (Fig. 2) (21). Aiming to standardize a reporting formula, we had applied the European Society of Gastrointestinal and Abdominal Radiology consensus of VC reporting, which had been published as CT Colonography Reporting and Data System (C-RADS) Table 1 (22).

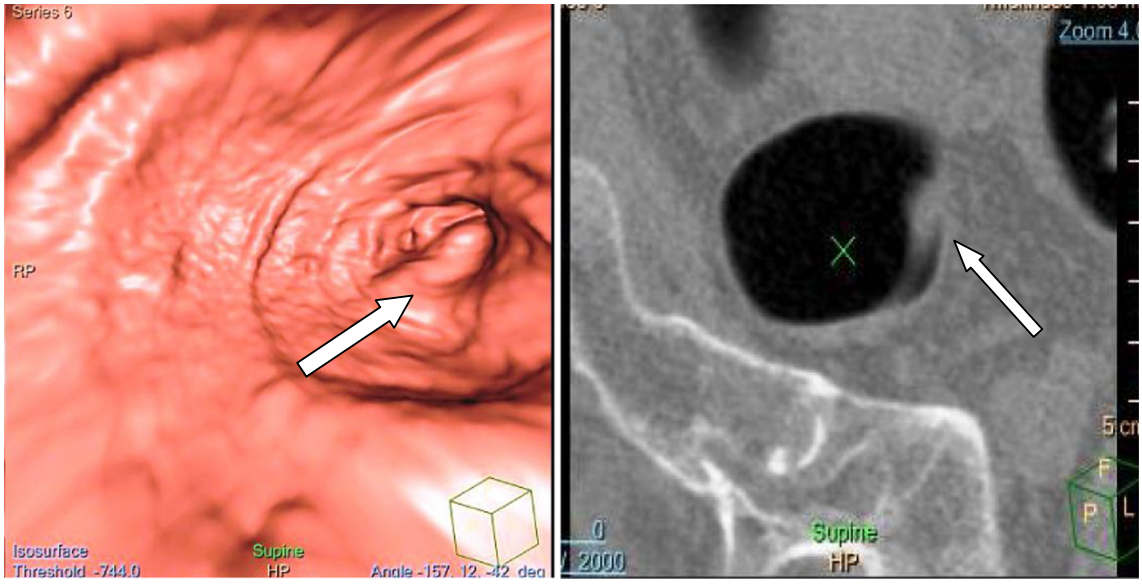
4. Results

3D navigation showed false positive results such as pseudopolyps in 35 (17.5%) patients due to residual feces (Figs. 3–5), 4 (2%) patients due to under-distended colon (Fig. 6), 2 (1%) patients due to segmental spasm (Fig. 7), 6 (3%) patients



A B

Fig. 8 (A) Filet VC image showing irregular surface with polypoidal projections (Arrow), due to motion respiratory artifacts as seen in corresponding 2D images.



A B

Fig. 9 (A) Pseudopolypoidal apparent swelling in supine VC images (Arrow), which was proved to be prominent haustral fold in corresponding 2D image (Arrow in B).

due to motion artifacts (Fig. 8), 17 (8.5%) patients due to prominent haustrations (Fig. 9), 9 (4.5%) patients due to prominent ileocecal valve (Fig. 10), one (0.5%) patient due to prominent appendicular stump and False pits simulating diverticula, due to shine-through effect, were also seen in 3 patients (1.5%) (Fig. 11). 3D VC navigation false negative results were encountered in the following: 3 (1.5%) patients due to residual stool, 5 (2.5%) patients due to residual fluid, 10 (5%) patients due to colonic under-distention, 2 (1%) patients due to prominent colonic folds (Figs. 12 and 13) and 2 (1%) patients due to sessile shallow polyps (Fig. 14) Table 2.

Additional 2D navigation showed no false positive results. Only 7 cases (3.5%) had false negative results due to different combinations of fecal residue in 6 patients (3%), too much retained fluid in 4 patients (2%), underdistension in 2 patients (1%), prominent haustrations in 5 patients (2.5%) and sessile polyps in 2 patients (1%) (Figs. 13 and 14) Table 2.

7–10 days after CT scan, confirmatory screening with conventional colonoscopy was done for all candidates, proving

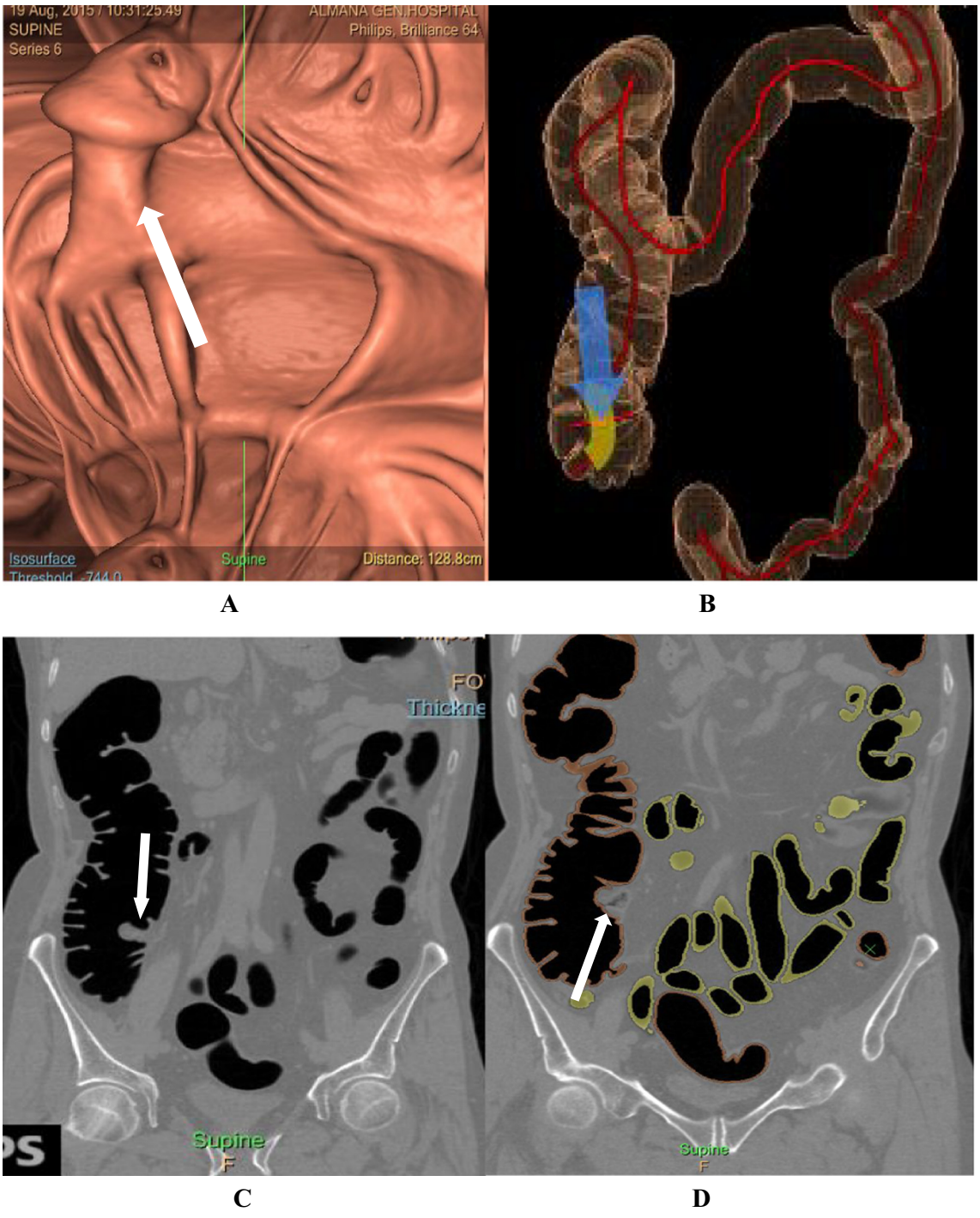


Fig. 10 (A) VC image showing cecal polypoidal like structure (Arrow). (B) VC navigation scout locating the corresponding point in the cecum (Arrow). (C) Corresponding coronal 2 D supine image showing the polyp like projection to be at the assumed position of ileocecal valve (Arrow). (D) Corresponding coronal 2 D prone image showing the polyp like projection to be evidently an ileocecal valve. (Arrow).

positive results in 102 patients and negative results in 98 patients. This had documented that 3D navigation got final results of the following: 80 (40%) true positive cases, 59 (29.5%) true negative cases, 39 (19.5%) false positive cases and 22 (11%) false negative cases giving results to 78.4% sensitivity and 60.2% specificity records. 2D navigation was notarized to get 95 (47.5%) true positive cases, 98 (49%) true negative cases, no false positive results, 7 (3.5%) false negative results giving 93% sensitivity and 100% specificity records (Figs. 13 and 14) Table 3.

5. Discussion

Among different steps of VC imaging process, improper bowel cleansing before insufflation is considered to be the most frequently encountered interpretation misleading factor, due to residual stool and/or fluid. Residual fecal matter can be fal-

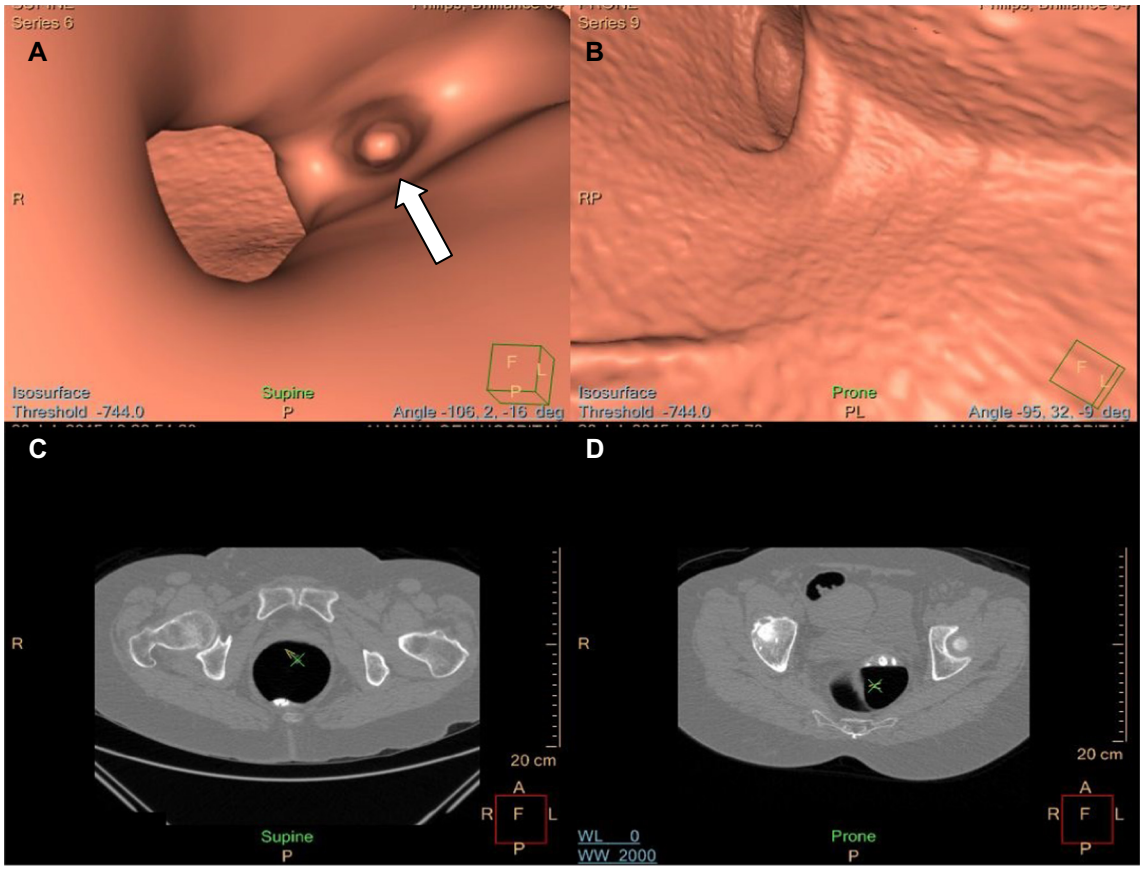


Fig. 11 Shine through artifact is seen as diverticulum like pit (Arrow), in 3D VC supine images (A), due to suboptimal reconstruction with reduced-perspective SSD threshold, disappearance of the artifact is noted at corresponding prone VC image (B) due to reconstruction with higher SSD threshold. Diverticulum is not seen at confirmatory corresponding axial 2D images at supine (C) and prone (D) positions.

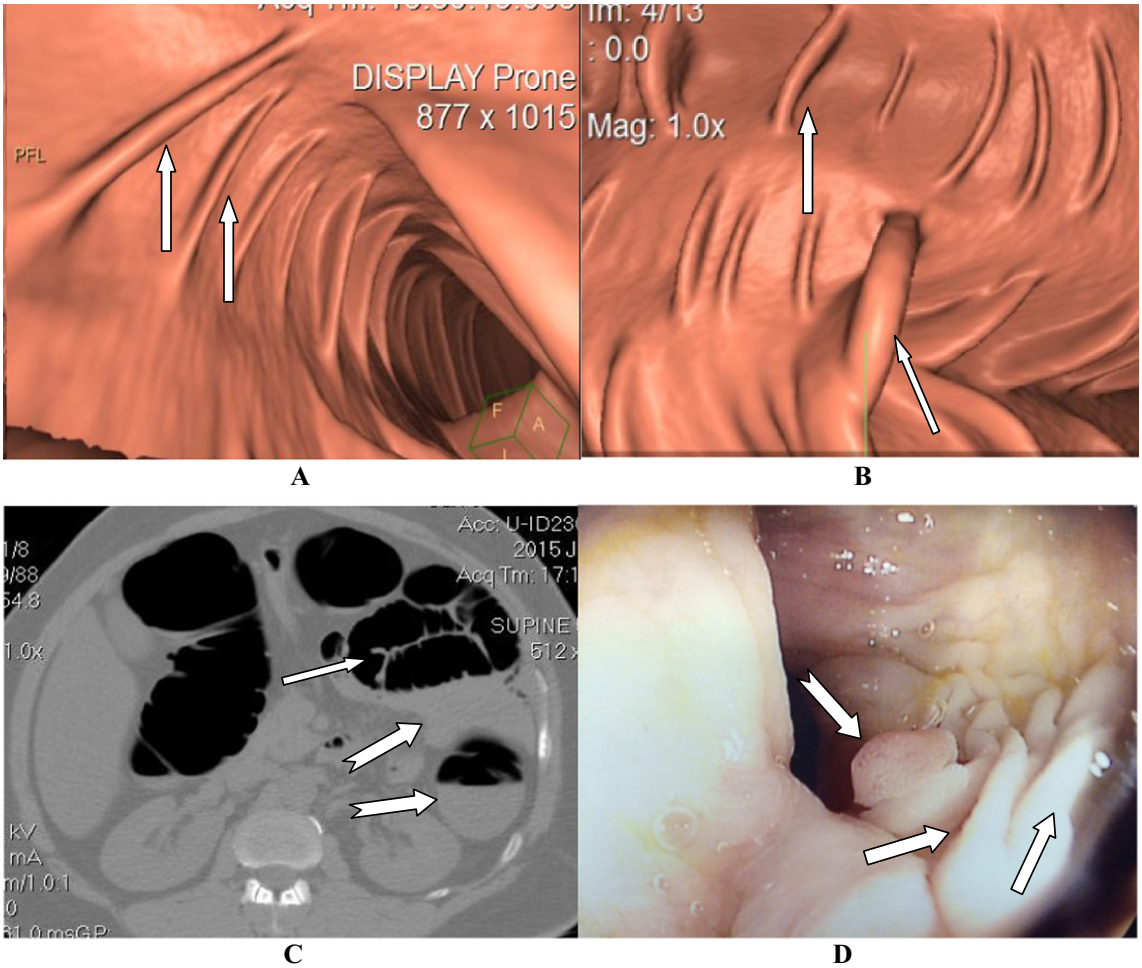
sely interpreted as colonic polyps in 3D navigation, which may lead in turn to unnecessary invasive procedures. This is due to variable morphological features of the residual fecal matter that may simulate polypoidal growths in 3D VC navigation images, as seen in 35 (17.5%) cases of this study (Figs. 3–5). This pitfall probably occurs in reports that rely only upon 3D plans revisions, in the process of VC interpretation. Simultaneous regional correlation of 3D images with the corresponding 2D images is decisive, through demonstration of fecal tagging, trapped gas, as well as changing position to the dependent side in the corresponding counter position. These three signs are agreeably considered the landmarks of these fallacious polypoidal swellings to be confidently interpreted as fecal residue (23–25). Similar findings were described in 2007 published study, edited by Park S. et al. (25).

Sometimes, it is more difficult to assure the fecal nature of these pseudo-swellings, if they lack air pockets and are adherent to the wall i.e. immobile with patient's position changes. This makes fecal residue to more complexly resemble small polyps in 3D navigation images. However, they can be still differentiated by simultaneous careful revision of the corresponding 2D images, for checking stool tagging with oral contrast. At last, if there is no appreciable fecal tagging with still controversial images, intravenous contrast is required, as polyps and masses will enhance, but stool will not. Fortunately intravenous contrast material is not frequently needed for such differentiation, as we experienced in our study. However, some authors favor the use of IV contrast in VC examinations, as they believe that addition of an intravenous contrast medium can help avoid these fecal residue pitfalls in interpretation (26,27).

Regardless of all attempts to eliminate residual fluid before VC examination of our patients, some patients still had some considerable amount of residual fluid, which was seen as horizontal air fluid level in the dependent parts of the colon on 2D images. This is considered as an obscuring factor which may conceal different colonic lesions, giving false negative reports, as we faced in 4 patients. Turning patients in both prone and supine positions will displace small amounts of retained fluid into the dependent side and to other colonic segments, avoiding its concealing effect. However, larger amount of retained fluid could not be simply shifted by position changes, with still possible images distortion, as we suffered in this study in both 2D and 3D navigations (Table 2 Fig. 13). This excess fluid could be avoided through pre-examination preparation with cathartic drying agents such as dulcolax (bisacodyl), which is muscle stimulant laxative (28–30).

A B

Fig. 12 (A) 3D VC filet view showing extensive scattered colonic diverticula (Chevrons), that were initially hidden beyond thick luminal folds in corresponding 3D VC supine navigation (B).



A B

C D

Fig. 13 VC false negative case: (A) 3D navigation, (B) corresponding filet image and (C) corresponding 2D image showing prominent left colonic haustration (Arrows) and large amount of retained fluid (Notched arrows in C), with no definite polypoidal growth. (D) Corresponding left colonoscopic image at the same ROI showing prominent haustration (arrows), surrounding short necked polypoidal lesion (Notched arrow).

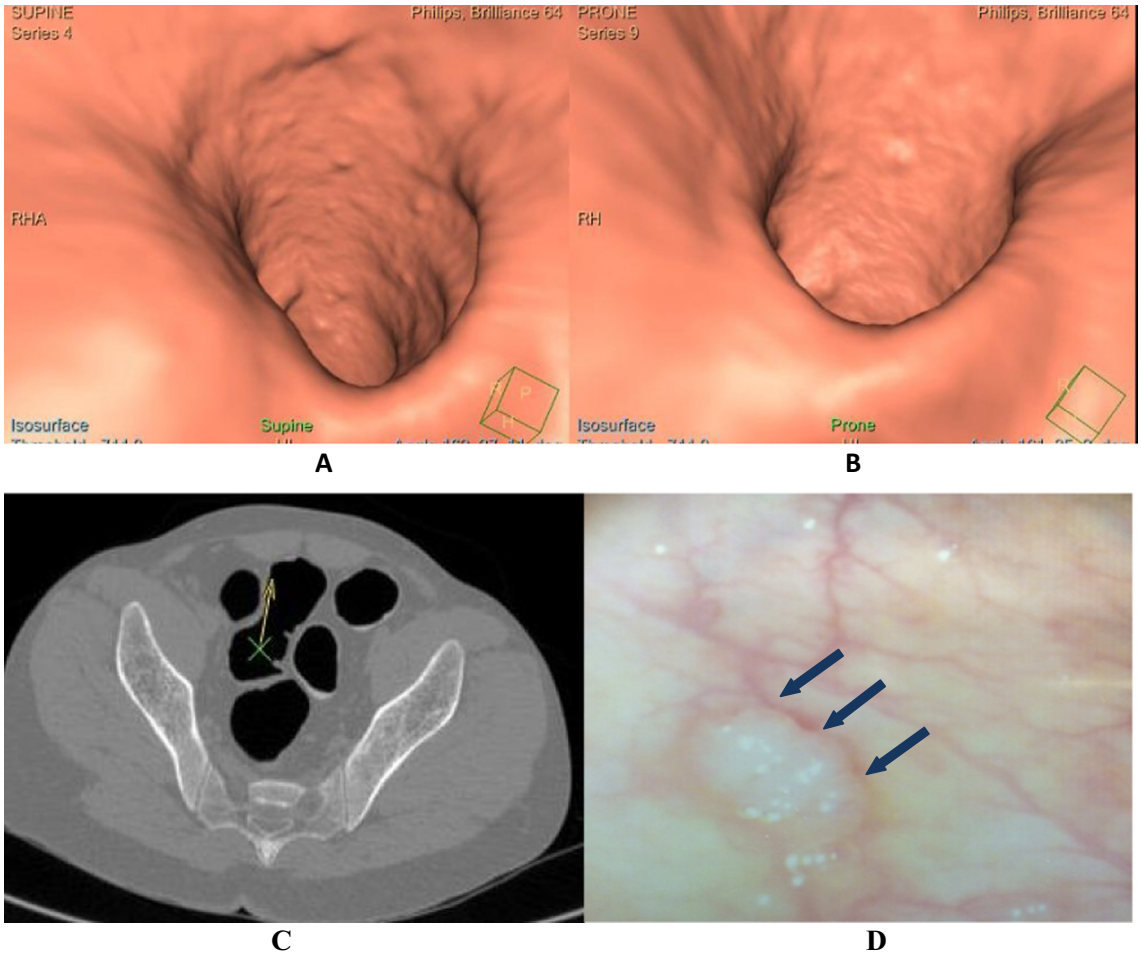


Fig. 14 Sessile sigmoid polyp with false negative VC navigation: (A) Supine & (B) prone 3D VC navigation and (C) corresponding 2D axial CT image showing no impressive findings, in contrast to the corresponding conventional colonoscopy photograph (D) which clearly shows small sessile polyp (Arrows).

Table 2 Causes and solutions of the recorded 2D and 3D VC navigation errors.

Causes of errors	3D		2D		Solution
	False+	False−	False+	False−	
Residual stool	35 (17.5%)	3 (1.5%)	0	6 (3%)	Tagging and 2D revision
Retained fluid	0	5 (2.5%)	0	4 (2%)	Change position (supine and prone)
Underdistention	4 (2%)	10 (5%)	0	2 (1%)	Scout check
Spasm	2 (1%)	0	0	0	Antispasmodics + insufflation
Respiratory motion artifacts	6 (3%)	0	0	0	Breath hold and short scan time
Prominent colonic folds	17 (8.5%)	2 (1%)	0	5 (2.5%)	Filet review.
Ileocecal valve	9 (4.5%)	0	0	0	2D revision
Appendicular stump	1 (0.5%)	0	0	0	2D revision
Shine through	3 (1.5%)	0	0	0	2D revision/increase PSSD threshold
Sessile polyps	0	2 (1%)	0	2 (1%)	Conventional colonoscopy

PSSD: perspective shaded-surface-display

In contrast to the commonly used VC prospective bowel preparation technique, which includes strict unpleasant diet instructions and drug induced cathartic regimen, there is newly applied CT retrospective electronic cleansing technique, called laxative-free technique. This is an evolving software technique for removing fecal residue materials from CT colonographic images, after image acquisition. It cleanses tagged fecal materials that can obscure the colonic mucosal surface, especially small lesions that are concealed by or adjacent to the tagged materials. However, electronic non-cathartic cleansing technique still causes some artifacts in VC images, e.g. Soft-tissue degradation, pseudo-soft-tissue structures, and incomplete cleansing, which impair the quality of VC images and limit

Table 3 Overall results of the study.

Examination	True +ve	True −ve	False +ve	False −ve	Sensitivity (%)	Specificity (%)
VC 3D	80 (40%)	59 (29.5%)	39 (19.5%)	22 (11%)	78.4	60.2
VC 2D	95 (47.5%)	98 (49%)	0	7 (3.5%)	93	100
Conv. colonoscopy	102	98	–	–	100	100

- Conv.: Conventional
- False +ve: false positive
- False −ve: false negative.
- VC: Virtual colonoscopy

the diagnostic utility of this modality. So, we preferred not to apply it in our studies protocols (31).

Colonic distention is mandatory for attaining perfect VC images and accurate correct interpretation. Insufficient distension is often associated with apparent colonic stenosis, which may be falsely considered as pathological stenosis or may hide some small lesions, as encountered in this study (Table 2, Fig. 6). So, adequate distension should be confirmed before start of scanning by revision of the scout view after the insufflation of gas into the colon; additional gas should be insufflated to distend collapsed segments. CO_2 could be used instead of room air for colonic insufflation, with some authors' reports that it is more comfortable for the patient and gives better colonic distention. For both room air and CO_2, there are no standard volume figures for gas insufflation, but it should be individualized through careful prescanning scout checking (32,33).

Physiologic segmental colonic spasm, which was uncommonly encountered during manual insufflation, could be explained by the segmental muscular contraction induced by manual rapid high pressure series insufflation. Sometimes, it may simulate pathological stenosis with shoulder such as margins, or marginal sessile polyops (Fig. 7). If this segmental narrowing was noted in first run revision, we used to insufflate more gas, in order to distend collapsed segments in the second series. Also, if a patient experienced considerable pain during rapid manual air insufflation, it was ordered to slow down insufflation rate to avoid spasm induction. Hence, the importance for the responsible radiologist was to monitor the examination and keep eyes on images and patients during the scanning procedure, as we used to do in our VC examinations (32).

Although the use of antispasmodic drugs as routine preparation schedule is still controversial, we used to give intravenous antispasmodic drug (20 mg/1 ml hyoscine diluted in 10 ml normal saline), slowly over 3–5 min before starting insufflation in order to avoid pain and spasm. This manual insufflation induced spasm explains why some institutes prefer the use of automated pressure controlled insufflator, as it stops with predetermined higher colonic pressure level, getting an advantage over manual insufflation, which does not take account of colonic pressure (33).

Respiratory motion, if not controlled, may cause sectional misregistration and violates imaging quality. In this study, this was uncommonly suffered by few candidates that were initially dyspneic patients and can't withstand breath hold for the whole examination time. These motions artifacts may be falsely seen as pseudopolypoidal swellings in 3D images due to linear artifacts, seen on the opposing surfaces of the affected colonic segment. However, this could be easily identified in reviewing the corresponding 2D images of the same location, which clearly demonstrate colonic and abdominal wall irregularity due to these respiratory artifacts, as followed in this study (Fig. 8). Fortunately, this artifact was so limited with 64 MSCT scan used in the study, whose average total abdominal scan time was usually less than 12 s (34).

Prominent colonic folds could sometimes appear as polypoid lesions in 3D and/or in profile of 2D images, and also may hide small polyps or diverticula (Figs. 9, 12 and 13). This was commonly seen at sites of colonic flexures, as these sites were the most frequently suboptimally distended sites (29). This could be overridden on workstation, by confirmation of the linear configuration of these folds through continuous cine review of corresponding 2D images. Also, filet navigation can be very helpful in correcting these artifacts and avoiding such misjudgment. However, smaller lesions could be still missed e.g. Small sessile polyps or shallow diverticula (Figs. 12 and 14), that may be only diagnosed by conventional colonoscopy (23).

Also ileocecal valves, when of papillary type, were seen sometimes as polypoidal growth on the medial aspect of the cecum at 3D images (Fig. 10). So, it was crucial to identify and localize the ileocecal valve in axial 2D images as landmark, in correspondence with its site at flythrough 3D navigation (35). Uncommonly, if there is an inverted appendiceal stump, it may attain polypoid configuration in the cecum at the expected site of the excised appendix. History of appendectomy, in combination with missed appendix in 2D images can help to avoid misinterpretation. Controversially, an inverted appendiceal stump could hide adjacent true cecal polyp in 3D VC images, as reported in some literatures and may also represent true neoplastic growth on the assumed site of appendectomy. Thus, for some debatable post-appendectomy cases, close interval VC follow-up/colonoscopy recommendation may be indispensable (36,37).

Although uncommonly seen in recent VC reconstruction software, suboptimal 3D reconstruction settings using perspective shaded-surface-display [SSD] threshold can lead to shine-through artifacts, simulating diverticula or ulceration. These artifacts often appear in areas where the colon is not directly surrounded by pericolic tissues and the colonic wall is adjacent to other bowel segments, or perhaps in haustral folds. On corresponding 2D images, no wall defects corresponding to 3D features are present, as demonstrated in our study (Fig. 12).

Adjustment of opacity settings for volume-rendered images or an increased-perspective SSD threshold is helpful in overcoming these pitfalls (38).

Finally, conventional colonoscopy is the standard last resort for confirmation of the presence or absence (Fig. 13), as well as pathological evaluation and sometimes interventional management of different colonic lesions. The value of well done and well interpreted VC CT scan studies is to limit such invasive coasty procedures to pathological evaluation and interventional removal of hazardous lesions, confidently diagnosed with VC (39).

6. Conclusion

- This study approved that, regardless of the high sensitivity of VC imaging technique, defective patients' preparation, insufficient radiology staff's technical awareness and some other unavoidable factors, such as sessile lesions or inverted appendectomy or prominent ileocecal valve are the main incriminated risk factors of perception and interpretation errors in VC studies.

Recommendation

- In order to attain the highest possible accuracy in VC imaging studies with avoidance of many pitfalls, it should be emphasized that 2D and 3D VC navigations are complementary not substitutional to each other, so they should be always reviewed in combination.
- All possible technical errors can be simply avoided, through encouraging interested radiologists to be acquainted by and familiar with the traps of pseudolesions and how to avoid their occurrence or misinterpretation.

Conflict of interest

The authors declared that there is no conflict of interest.

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