VIRTUAL COLONOSCOPY AND 3D RECONSTRUCTION IN COLORECTAL CANCER PATIENTS

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Summary

Introduction: Virtual endoscopy of the colon or virtual colonoscopy (VC) is a technique for postprocessing high resolution helical CT datasets. 3D surface rendering volume reconstruction that simulates endoscopic views of the inner surface of the colon was performed in real time by means of computer generated ray casting. VC may be performed together with 3D volume rendering (3DVR). VC can be applied in teaching, diagnostics, intervention planning or intraoperative navigation and as a non-invasive technique it is particularly useful when the patient cannot tolerate classical fiberoptic endoscopy.

Objectives: To implement VC as a new technique of high resolution helical CT data postprocessing in screening, preoperative diagnostics and management and to discuss advantages and disadvantages of the method.

Methods: VC and 3DVR in space analysis were performed using Syngo 2006G platform by Siemens Medical Systems in: a 46-year-old man with a spastic colon and some intestinal diverticula and polyps, a 65-year-old man who underwent endoscopic removal of a large colorectal polyp, a 64-year-old women with large circular cancer stenosis of the rectum and right hepatic lobe metastatic lesion, and a 52-year-old man with a large endoluminal cancer mass in the sigmoid colon. Virtual colonoscopy was performed in real time using ray casting algorithm with space leaping acceleration method. Siemens Somatom Emotion 16 scanner was used for image acquisition. Postprocessing of the images stored in DICOM format was done by dual Xeon workstation.

Results: Fly through algorithm and 3DVR were performed on data sets created from axial CT images collected from multislice helical CT scanner archived in DICOM format. Fly through and 3DVR postprocessing produced a series of images that were analyzed by one radiologist, two surgeons and two physicians experienced in virtual endoscopy.

Conclusion: VC is a useful non-invasive method in the assessment of malignant and benign lesions of colon. It may provide useful additional information for a surgeon during preoperative management. Furthermore, it allows three-dimensional visualization in the lumen beyond areas of narrowing or stenosis and it gives a highly accurate representation of colorectal lesions. Its disadvantages are that it does not provide histology, it requires an air-mucosa interface to produce an image and it cannot identify functional lesions. Using VC, clinicians can appreciate not only the intraluminal proliferation of the tumor but also the extraluminal extension of the mass and its relation to the surrounding organs.

KEY WORDS: high resolution computed tomography, virtual colonoscopy, 3D volume rendering, colorectal cancer

VIRTUALNA KOLONOSKOPIJA I 3D REKONSTRUKCIJE U BOLESNIKA S KARCINOMOM KOLONA I REKTUMA

Sažetak

Uvod: Virtualna endoskopijska kolonija ili virtualna kolonoskopija (VC) je metoda postprocesiranja podataka dobivenih kompjutoriziranom tomografijom visoke razlučivosti. VC simulira pogled pravog endoskopa na unutrašnju površinu debeleg crijeva, a izvodi se u realnom vremenu na računalnim radnim stanicama s pomoću računalnog algoritma “ray casting”. VC se može izvoditi zajedno sa trodimenzionalnim volumnim renderiranjem (3DVR) koje daje 3D prikaz promatranog dijela tijela. VC se može koristiti u edukaciji, dijagnostici, planiranju endoskopskih zahvata ili operacija, te intraoperacijskoj...
INTRODUCTION

Colorectal cancer represents the second leading cause of cancer death in the United States and also in most other industrialized countries. It accounts for approximately 10% of all cancer deaths in both men and women combined (1, 2). The majority of cases of colon cancer develop in patients without specific risk factors. The current recommendation for colon cancer screening in asymptomatic patients at average risk for colorectal cancer is that it should begin at age of 50 years (1).

In recent years, the incidence and mortality of colorectal cancer have declined. Early diagnosis and preventive removal of premalignant adenomatous polyps are believed to be the most probable reasons for a decrease in both incidence and mortality of colorectal cancer. This is related to the increased use of colonoscopy (3). However, the cumulative lifetime risk for the development of colorectal cancer is still approximately 5% (4).

It is generally accepted that the vast majority of colorectal cancers arise from adenomatous polyps. Bearing in mind that malignant transformation is found in approximately 1% of polyps of less than 10 mm in size, compared with 10% of larger polyps (5), early detection of colorectal polyps might be regarded as one of the major goals in health care management (3).

Several studies have focused on the role and principal characteristics of virtual endoscopy of the colon (virtual colonoscopy) in colorectal cancer prevention and detection (6-12).

Virtual colonoscopy has several advantages over existing colorectal cancer screening techniques. As a full structural colonic examination, its diagnostic potential should be much greater than fecal occult blood testing and, for the same reason, it should yield substantially more neoplasms than flexible sigmoidoscopy. As a total colonic examination it competes directly with barium enema and classical fiberoptic colonoscopy (8).

Complete colonoscopy allows the most thorough evaluation of the colon, with the added benefit of the ability to perform biopsy or excision of suspicious lesions. Colonoscopy is considered the reference standard for colonic evaluation (1, 3, 13).

However, there are several important limitations to the widespread use of screening colonoscopy (3), including the need for sedation, the po-
potential risk of perforation and bleeding (0.1%–0.3% of cases), the costs of the procedure (including the need for sedation), a failure to complete the ex-

Figure 1. 3DVR double air contrast reconstruction was performed after the air insufflation into the rectum. It may be used to estimate whether the air insufflation was successful. Furthermore, this method gives a general overview of the anatomical relationships of the large and partially of the small bowel. It is useful for clinicians to perform double air 3DVR before actual virtual colonoscopy or CT colonography because it may provide information which may be used by the clinician to make decision where to focus his attention during the virtual colonoscopy procedure. Sometimes cancer of a medium or large size may be revealed with this procedure. Relatively well colonic distention and cleansing in the 46-year-old man was shown.

Figure 2. 3DVR reconstruction of the same region using an algorithm for segmentation of colonic epithelial surface. The frontal clipping plane was used to remove some tissue in order to provide a clear fly-over view to the ascendant colon.

Figure 3. High resolution computed tomography accompanied with VC and 3DVR was performed in the 46-year-old man suffering from colonic cramps. Virtual endocamera was situated within the rectum lumen and its view focused upwards. VC working environment was divided in four windows. Virtual endocamera endoluminal position was shown in three main coordinate planes. Reconstructed endocamera view was presented in the fourth window. Endocamera view was focused in cranial direction within the sigmoid colon. Normal endoluminal appearance as presented by the fly-through procedure was shown.

Figure 4. 3DVR in space fly-over environment. HRCT reconstructions in three main coordinate planes were presented in the first three windows. In the fourth window, fly-over 3DVR reconstruction was performed. Part of the descendant colon was opened and functional circular stenosis due to colonic spasm was revealed. Colonic mucosa, its wall and surrounding tissue appearance around the colon was normal and without a sign of tumor.
amination in 5%–10% of patients, and an insufficient workforce of trained endoscopists to meet the increased demand (14, 15). For these reasons, virtual colonoscopy (CT colonography) is being investigated and used clinically to evaluate the colon for polyps and cancers (3, 6).

Clinical evaluation of virtual colonoscopy has shown promise for the detection of polyps and cancers of the colon and rectum, with per-polyp sensitivity values ranging from 75% to 100% for polyps 10 mm and larger (8). For thin-section multi-detector row CT, the per-patient specificity for lesions 10 mm and larger is greater than 95% (16, 17).

Several studies showed virtual colonoscopy to be as effective as conventional colonoscopy for
the detection of polyps 10 mm and larger (16, 18). However, fundamental differences between the two methods remain: biopsy specimens cannot be obtained by virtual colonoscopy, and surrounding tissues and anatomic structures in relation to endoscope position cannot be visualized during classical flexible endoscopy. Furthermore, due to the sedation medication, classical fiberoptic colonoscopy procedures usually require 30 minutes to 2 hours recovery time, while VC procedures require no recovery time.

Although VC is a non-invasive procedure, a colon preparation similar to that required for fiberoptic colonoscopy including Dulcolax, phosphosoda and oral contrast agents is used. During a VC procedure patients are exposed to a small amount of radiation. Since the procedure is non-invasive, there is no risk of colon perforation. There is no exposure to radiation during a fiberoptic colonoscopy procedure, but approximately 3 in 1,000-10,000 patients experience complications due to perforation.

3DVR has made significant contributions in surgical planning. A majority of surgical proce-
dyes involve a complex 3D relationship between
the affected tissue and adjacent anatomic struc-
tures (19).

The objective of this paper was to find out ad-
vantages and disadvantages of VC and 3DVR in
the screening and management of colorectal cancer
as well as to implement these methods in practice.

METHODS

MSCT of the abdomen accompanied by VC
and 3DVR postprocessing was performed in: a 46-
year-old man with a spastic colon and some intes-
tinal diverticula and polyps, a 65-year-old man
who underwent endoscopic removal of large
colorectal polyp, a 64-year-old women with large
circular cancer stenosis of the rectum and right hep-
atic lobe metastatic lesion, and a 52-year-old man
with a large endoluminal cancer mass in the sig-
moid colon.

Before MSCT scanning, all patients under-
went full bowel cleansing and air distension of the
colon using a rectal enema tube. A small rubber
catheter can be used to insufflate the colon. Acquisition of both supine and prone thin-section images of the colon was done by a Siemens Somatom Emotion 16 scanner (slice thickness 1.2 and 0.6 mm). Acquired images were stored in the DICOM format. Data interpretation was performed by a multidisciplinary team analyzing a combination of axial and multiplanar or endoluminal VC as well as 3DVR reconstructions. Postprocessing was done on a dual Xeon workstation using the professional 3D Syngo CT 2006G software package. Additional views and reconstructions not normally accessible by conventional endoscopy were generated.
RESULTS

Fly-through of the virtual endocamera within the bowel lumen was both manually and automatically driven. We interactively changed the camera 3D position and focus during examination using a mouse pointing device.

VE and 3DVR processing were performed by a multidisciplinary team – one radiologist, one general surgeon and two physicians experienced in VC.

DISCUSSION

Visualization of volumetric medical image data plays a crucial part for diagnosis and therapy planning. In recent years, computerized post-processing techniques of image data from cross-sectional imaging modalities have received increasing recognition in the field of medicine. Technical developments of acquisition systems such as multislice CT and MRI have improved along with continuously increasing spatial resolution. Various post-processing techniques have been available, to enable the radiologist or surgeon to recognize a pathological condition in the shortest amount of time: three 2D orthogonal views, maximum intensity projection (MIP), surface and 3D volume rendering.

The advancement of high resolution computed tomography with thin sections and intravenous contrast has greatly improved the clinician’s ability to diagnose various lesions, allowing for earlier detection and more accurate staging.

Virtual colonoscopy is a novel and rapidly evolving technique for colonic examination, and it is especially useful for colorectal cancer screening. Many factors influence successful performance of VC. An understanding of these factors and continued efforts to improve them will help ensure widespread implementation of VC into routine clinical practice. (20) Virtual colonoscopy may improve colorectal screening by facilitating detection of clinically important colorectal polyps with the use of a relatively noninvasive safe examination,
thereby increasing patient and clinician acceptance of colon cancer screening (8, 21).

Some studies reported that with interrogation of 3D endoluminal images in both anterograde and retrograde directions, smaller polyps (up to 5 mm) can be routinely detected by virtual colonoscopy (16).

The polyp size is clinically a single, the most important feature of a colorectal polyp because it serves as a rough gauge for the risk of carcinoma and so it dictates patient care. Therefore, polyps should be measured accurately and reliably at VC and patient management should be done according to the reported polyp size. Polyps measuring 10 mm should be reported with a recommendation for therapeutic colonoscopy (22, 23).

Reporting of polyps measuring 5 mm is not recommended because they often represent false-positives and they are frequently non-neoplastic or are associated with an extremely low risk of malignancy (22, 23). The potential harm of fiberoptic colonoscopy may outweigh the benefits for patients with diminutive polyps. Reporting of polyps measuring between 6-9 mm varies, depending on the specific lesion size, the certainty of the findings, patient’s age and existing comorbid conditions (22). One guideline that used the CT Colonography Reporting and Data System (C-RADS) classification scheme suggested immediate colonoscopy for patients with three or more 6-9 mm polyps and follow-up colonoscopy should be done in three years for patients with less than three 6-9 mm polyps (23).

The current reimbursable classical methods available for colorectal carcinoma screening include fecal occult blood testing, sigmoidoscopy, double contrast barium enema examination, colonoscopy, and combinations of these tests.

Screening sigmoidoscopy has been shown to decrease the mortality due to colorectal cancer. However, sigmoidoscopy is not an evaluation of the entire colon, and, therefore, complete colon screening is not achieved.

Classical fiberoptic colonoscopy is considered the reference standard for colonic evaluation (1, 13), but it has several important limitations to be used for screening including the need for sedation, the potential risk of perforation and bleeding, the costs of the procedure and sedation, a failure to complete the examination in 5%–10% of patients, and an insufficient workforce of trained endoscopists to meet the increased demand (14, 15). For these reasons, virtual colonoscopy (CT colonography) is being investigated and used clinically to evaluate the colon for polyps and cancers.

There are many factors affecting the successful performance of VC. Adequate colonic cleansing and distension, the optimal CT technique and interpretation with using the newest VC software by a trained reader will help ensure high accuracy for lesion detection. Fecal and fluid tagging may improve the diagnostic accuracy and allow for reduced bowel preparation. Automated carbon dioxide insufflation is more efficient and may be safer for colonic distension as compared to manual room air insufflation. CT scanning should use thin collimation of 3 mm with a reconstruction interval of 1.5 mm and a low radiation dose. There is not any correct method for the interpretation of VC, therefore, readers should be well-versed with both the primary 3D and 2D reviews. Polyps detected at VC should be measured accurately and reported following the polyp size-based patient management system (20).

On one hand, IV contrast enhancement is helpful for differentiating polyps from fecal residues (24, 25) and for improving the detection of polyps in suboptimally prepared colons (26). Yet, it is not routinely used with screening CTC due to its risk and uncertain cost-effectiveness (22). On the other hand, IV contrast enhancement is important for the detection and characterization of clinically significant extracolonic abnormalities. Therefore, it is necessary to use contrast enhancement for patients with known colorectal cancer or if they have the suspicion of it, for patients who are followed up after curative surgery for colorectal cancer and for those patients with symptoms that suggest an increased prevalence of extracolonic abnormalities (22, 27).

CONCLUSIONS

Virtual colonoscopy is a useful non-invasive method for screening and the assessment of malignant and benign lesions of the colon. It is especially useful for colorectal cancer screening. Many factors influence the successful performance of VC. An understanding of these factors and contin-
ued efforts to improve them will help ensure widespread implementation of VC into routine clinical practice. VC may provide useful additional information for a surgeon during preoperative management. Its disadvantages are that it does not provide histology, it requires an air-mucosa interface to produce an image and it cannot identify functional lesions.

REFERENCES


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