Virtual Scopy with Multidetector CT

Surg Cdr IK Indrajit*, Surg Capt JD Souza⁺, Surg Cdr R Pant[#], Surg Cdr PC Hande**

Abstract

Virtual scopy is a computerized, non-invasive technique used in simulating views provided by a fiber optic endoscope. Multidetector CT (MDCT) enhances the technique of Virtual scopy, by its z-axis resolution, faster data acquisition and improved 3D-image quality. The common application included Virtual Colonoscopy, Bronchoscopy, Gastroscopy, Angioscopy, Labyrinthoscopy, Thoracoscopy and Stentoscropy. Of the 45 Virtual scopies referred to Radiology Department at INHS Asvini, the single largest application was Virtual Angioscopy followed by Stentoscropy and the smallest was evaluation of larynx, labyrinth, colon and mediastinum accounting for 3 each. Endoscopy data and histopathological diagnosis was available in 17 patients, who underwent Virtual studies of larynx, airway, stomach, mediastinum and colon.

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Introduction

Virtual scopy is a computerized, non-invasive, evaluation of anatomical structures inside body cavities and hollow viscera, simulating a fiber optic endoscopy [1]. From high resolution CT data, virtual endoscopy reconstructs a 3D virtual model of the hollow organ and allows navigation inside it [2]. The earliest applications of VE were Colonoscopy, Bronchoscopy, Gastroscopy, Cystoscopy, Angioscopy and of late its range of applications extended to Labyrinthoscopy, Thoracoscopy and Stentoscropy [3].

Material and Methods

Patients

Virtual scopies were performed in 45 cases referred to Radiology Department at INHS Asvini. CT Colonography, was performed after standard preparation and colonic distension immediately before the exam with room air. Scans in prone and supine position were performed to shift residual intraluminal fluid. In CT Gastroscopy patients received 250 mL of water followed by ingestion of an effervescent agent Eno, to produce negative contrast. For Virtual Cystoscopy, the scans were performed in supine and prone position after injection of air via Foleys catheter into urinary bladder. For Virtual Angioscopy and Stentoscropy, 120 cc of Omnipaque 300 contrast was injected at the rate of 3ml/sec using a pressure injector and Care Bolus triggering software.

Scanning Techniques

Virtual scopic studies were performed using a multislice technique with a Somatom Sensation 4 Multidetector scanner (Siemens, Erlangen), equipped with an adaptive array matrix, a gantry rotation time of 0.5 sec, Medrad Vistron Pressure

injector and CARE Bolus software. In most cases, a detector configuration of 4 x 1 mm, a table feed of 5 mm/rotation at 140 mAs, 120 kV and a gantry rotation time of 500 msec was used, resulting in a slice thickness of 0.5 mm.

Processing of Image Data

Images from all 45 cases were first interpreted using cine viewing of axial images and secondary MPRs on the main console. Subsequently, volume rendering, 3D scopic views and fly-throughs were generated on a dedicated Leonardo workstation. Virtual scopy images were generated using volume and surface rendering. Four distinct data parameters, i.e. window width, level, opacity and brightness were interactively adjusted, influencing the images generated.

For Virtual Colonoscopy, a colon model was created with segmentation of the colon. Guided navigation using a centerline simulated a flight path of the entire colon. With real-time volume rendering at more than 10 frames/sec, interactive navigation of the endoscopic views analysed the colonic lumen. 2-D views corresponding to the navigation viewpoint were available for verification purposes. By turning, zooming, and rotating during the "fly-through" examination of the endoscopic views, the structures were more closely examined.

Results

Of the 45 Virtual scopies performed, the single largest application was Virtual Angioscopy followed by Stentoscropy. The smallest sub-groups were evaluation of larynx, labyrinth, colon and mediastinum accounting for 3 patients each. Endoscopy data and histopathological diagnosis was available in 17 patients, who underwent virtual studies of larynx, airway, stomach, mediastinum and colon. Of the 17 cases, the CT scopy diagnosis matched with Endoscopic/

***Classified Specialist (Radiodiagnosis and Imaging), INHS Asvini, Mumbai 400 005, *Senior Advisor, (Radiodiagnosis and Imaging), INHS Asvini, Mumbai 400 005, #Reader, Department of Radiodiagnosis and Imaging, AFMC, Pune- 411 040.

HPE Diagnosis in 16 cases. One flat lesion of sigmoid colon, considered benign, was malignant on HPE. Expectedly, virtual studies of the vascular system and labyrinth did not have any clinical endoscopy correlation.

The Virtual Laryngoscopy group consisted of tumors like carcinoma epiglottis, supraglottic carcinoma and vocal cord papillomatosis. Virtual Labyrinthoscopy was used in evaluation of cochlear implants, Mondini defect (Fig. 1) and labyrinthine fistula associated with cholesteatoma. Virtual Bronchoscopy was performed in 3 cases of carcinoma lung (Fig. 2), sarcoidosis and tuberculosis. Virtual Thoracoscopy was used in cases of neurofibroma, teratoma and sarcoidosis. Stomach tumors evaluated in this series included carcinoma stomach oesophagogastric junction and leiomyoma (Fig. 3). 4 cases of carcinoma colon were evaluated by Virtual Colonoscopy.

Among the vascular group, 9 patients with either stenosis or aneurysms were subjected to Virtual Angioscopy prior to stenting and follow up post stentoscapy. The clinical entities included coarctation of aorta (Fig. 4), carotid artery stenosis,

Fig 1: Virtual Labyrinthoscopy in Mondini defect. The left panel shows an axial image of abnormal dysplastic cochlea. A Virtual labyrinthoscopic image of normal cochlea with its characteristic 2 ½ turns is seen below. The right panel shows a Virtual labyrinthoscopy image of the dysplastic single cavity cochlea lacking its normal 2 ½ turns.

Fig. 2: Virtual Bronchoscopic in bronchogenic carcinoma. The left panel shows an axial CT of a malignant mass compressing the right main bronchus. The right panel shows a Virtual bronchoscopic image depicting the narrowing with distal occlusion of right main bronchus.

subclavian artery aneurysm and aortic aneurysms.

Discussion

Virtual scopy is a specialised medical application of Virtual Reality, with fly-through and fly-around function on 3D data subject to surface or volume rendered images. The term “Virtual Endoscopy” comprises of two distinct entities: “Virtual” denotes “certain physical virtues” while “Endoscopy” is defined as “visualizing the interior of a hollow organ” [4]. Investigators conducting research in Virtual Imaging were Vining on Virtual Colonoscopy, Lorensen on 3-D fly-through imaging of carotid arteries and Robb on interactive organ fly-throughs [4].

A fly-through reconstructs an image with rotation

Fig. 3: Virtual Gastroscopy in a recently biopsied leiomyoma at lesser curvature. The left panel shows coronal MPR image of the virtual camera fly path from fundus to pylorus, over the lesion. The right panel shows a Virtual gastroendoscopy fly-around image viewed from greater curvature. The fundus is at right, while pylorus is at left with the leiomyoma with the biopsy defect in the centre.

Fig. 4: Virtual Angioscopy in a young hypertensive presenting with coarctation of aorta. The left panel shows MPR images depicting the narrowed segment of thoracic aorta, distal to origin of left subclavian artery, with presence of collaterals. The right panel shows an endoluminal image of thoracic aorta viewed from above. A fig shaped diaphragm represents the coarctation, beyond which the normal calibrated thoracic aorta is seen distally.

similar to a complex camera shot, using a path or line on which the virtual camera is traced. A fly-around reconstructs a structure within a volume for protracted viewing, gaining a different vantage point. Kinetic and Stereo Depth Cues are two specialised techniques assisting scopies, with former improving spatial interpretation by viewing an object in motion, and latter conveying depth perception by integrating capability of brain o stereopsis. There are many factors which influence the images generated during Virtual Scopies (Table 1).

In Virtual Colonoscopy, two approaches to colon evaluation are commonly performed. The first technique involves scrolling a stack of 2D images at lung window settings for evaluation of air-filled colon. The second approach uses image segmentation to create a 3D colon model to virtually navigate, either automatically or interactively. Virtual Colonoscopy by Multidetector CT improves the detection rate of small colorectal polyps compared to single-slice CT and approaches the reported rate for detection of polyps smaller than 6 mm by conventional colonoscopy. In the largest prospective study published to date by Yee et al the sensitivity of single-slice CT Colonography for polyp detection was 90% for polyps 10 mm or larger, 80.1% for polyps 5-9 mm and 59.1% for polyps smaller than 5 mm (overall sensitivity 69.7%) [5]. Virtual colonoscopy's sensitivity is related to polyp size, air insufflation and type of polyp. The sensitivity of virtual colonoscopy is higher for adenomatous polyps, a precursor to colorectal cancer, than for hyperplastic polyps. False-negative results occur with flat lesions and inadequate insufflation, while false-positive results are often due to residual feces [6]

Virtual Bronchoscopy generates an endoscopist's view of the tracheobronchial, lobar, segmental and sub segmental bronchi lumen and airway walls, offering useful information on the location, severity, and shape of airway narrowing [7]. By combining axial lung images the exact pathway for bronchoscopy procedure can be planned as in cases with foreign body, in determining the type of treatment of bronchogenic carcinoma and in transbronchial, transtracheal or transcarinal needle

biopsies (Fig. 2). It enables visualization of bronchial tree beyond an obstructive lesion while permitting a retroscopy: looking back at the distal part of stenosis. However, pitfalls such as inability to identify mild stenosis, submucosal infiltration, and superficial spreading tumors, occur occasionally.

In Virtual Labyrinthoscopy, we followed the recommendation of creating two 3D data sets: the first containing the whole scanned volume and the second containing the region of interest [8]. Using the latter along with clip planes, a narrow field of view with a higher in-plane resolution advantageously segments the volume to a focused area of cochlear structures (Fig. 1).

A recent study of 26 patients suspected to have bladder neoplasms were evaluated with virtual and conventional cystoscopy [9]. 36 (90%) of 40 bladder lesions proved at cystoscopy were detected with a combination of transverse and virtual CT images, while 4 lesions, all smaller than 5 mm, were undetected. The study revealed that CT with patients in both supine and prone positions was necessary, since 7 (19%) and 5 (14%) of 36 lesions were seen only on supine and prone images, respectively.

Virtual Angioscopy is a non invasive procedure, supported by real-time navigation that assesses vessel surface, caliber and orifices of take-off vessels. Novel features available in most current CT machines includes interactive tissue classification that separates and applies different colours to thrombus, plaques, calcification, stents and endoleaks (Fig. 5). Virtual Stentoscapy

Fig. 5 : Virtual Angioscopy and Stentoscapy in a case of abdominal aortic aneurysm. The left panel shows a coronal VR image displaying the location, size and relationships of the aneurysmal dilatation of aorta. The right panel shows a Virtual angioscopy image above displaying the endoluminal view of dilated aorta and a Virtual stentoscapy image below depicting the endoluminal view within stent graft, with no evidence of in-stent stenosis or thrombosis.

Table 1
Important issues in virtual scopy

No	Parameters
1	Structure evaluated : Air / Contrast / Soft Tissue / Bone
2	Position of Virtual Camera
3	Orientation of Virtual Camera
4	View Piece of Virtual Camera: Tele or Wide View
6	FOV of Virtual Camera : Near or Distant Field
7	Navigation with fly-through path : Push / Pull
8	Rotation of Virtual Camera : Rotate / Rotate and Translate
9	Movies : Forward and Reverse direction

expands the role of angioscopy, and is particularly valuable in estimating stents patency. Mallouhi et al evaluated 16 patients with renal artery stents with MDCT renal angiography and digital subtraction angiography [10]. Correlations between restenosis severity measured with DSA and those measured with MDCT were significant. Volume-rendered MDCT angiography enabled high-quality 3D reproducible evaluation of the patency of implanted renal artery stents.

Virtual scopy is non-invasive and free of side effects such as perforation and infection. It explores body regions not accessible to conventional endoscopy and can cross strictures. Its angioscopic applications assist in visualizing vessel orifices and analysing intimal flaps and mural thrombus. In vascular stenting it accurately identifies stent patency, migration, kinking and endoleaks. However, Virtual scopies requires state of art Multidetector CT and advanced computers. There is a dramatic overload of images, with a typical dataset comprising more than 800, 1-mm slices reconstructed at 0.5-mm intervals. Occasionally, artifactual lesions can be created, while mucosal irregularities can be missed. Moreover biopsy and interventional procedures cannot be performed.

Conclusions

Virtual scopy is a non invasive CT application for evaluation of anatomical structures inside human body. It avoids the risks associated with endoscopy, and can view regions not accessible to or compatible with endoscopy as in case of contents of labyrinth, thoracic cage and patency of stented vessels. With advances in MDCT scanners and refinements in technology, the value, utility and applications of Virtual scopy will significantly increase world over.

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