Computer Aided Diagnosis: Clinical Applications in CT Colonography

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27.1 Introduction

During the past decade, numerous attempts have been made to develop computerized methods that process, analyze, and display multidimensional medical images in radiology. A typical example is the three-dimensional (3D) visualization of semi-automatically segmented organs (e.g. segmentation of the liver, endoluminal visualization of the colon and bronchus), or image processing of a part of an organ for the generation of an image that is more easily interpreted by human readers (e.g. peripheral equalization of the breast in mammograms, digital subtraction bowel cleansing in virtual colonoscopy). These computerized methods often automate only one of the image-processing tasks and depend on user interaction for the remaining tasks.

Computer-aided diagnosis (CAD) goes beyond these semi-automated image-processing applications and steps into the area of medical image understanding or interpretation. In its most general form, CAD can be defined as a diagnosis made by a radiologist who uses the output of a computerized scheme for automated image analysis as a diagnostic aid. The concept of CAD is universal across different modalities and disease types. However, CAD is expected to be most beneficial for those examinations that became feasible only recently due to the advancement of digital imaging technologies, in which very many high-resolution images need to be interpreted rapidly to find a lesion with low incidence.

CT colonography (CTC), also known as virtual colonoscopy, is a promising alternative technique for screening of colon cancers (Levin et al. 2003; Macari and Bini 2005; Morrin and Lamont 2003). CTC typically uses a multi-detector CT scanner to obtain a series of cross-sectional images of the abdomen for detection of polyps and masses in the colon. The transverse CT images can be reformatted into multiplanar reconstruction (MPR) view for examination of the colon (2D reading), or they can be reformatted to a simulated 3D “endoluminal view” of the entire colon that is comparable to that seen with optical colonoscopy (3D reading). In this visualization mode, radiologists can “fly through” the virtual colon, from the rectum to the cecum and back, searching for polyps and masses. In any reading mode, radiologists can non-invasively examine the interior of the colon without physically invading it; thus, it is a safer procedure than optical colonoscopy.

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CAD for CTC typically refers to a computerized scheme for automated detection of polyps and masses in CTC data, whether they are 2D images or 3D volume (Yoshida et al. 2005a; Yoshida et al. 200b). It reveals the locations of suspicious polyps and masses to radiologists. This offers a second opinion that has the potential of improving radiologists’ detection performance, and of reducing variability of the diagnostic accuracy among radiologists, without significantly increasing the reading time.

During the last several years, rapid technical developments have established the fundamental CAD scheme for the detection of polyps, and commercial systems that implement the full CAD scheme or a part of it are becoming widely available (Yoshida et al. 2007). The latest CAD systems yield clinically acceptable high sensitivity and low false-positive rates, and thus CAD is becoming a major diagnosis aid for CTC. In the following sections of this chapter, we will describe the clinical benefits, principles, display modes, reader paradigms, known clinical performance of CAD and that of radiologists aided by CAD, and pitfalls of CAD.

### 27.2 Clinical Benefit of CAD

One of the major obstacles preventing CTC from becoming an effective means for polyp detection is that reader expertise is required for interpreting the CTC images – in particular, for detection of small polyps (Bodily et al. 2005; Burling et al. 2006; Fletcher et al. 2005; Slater et al. 2006). In particular, the detection performance among readers can be quite variable, which may be one of the factors for the large variation in the results of reported large-scale clinical trials (Fletcher et al. 2005). This problem is becoming substantial as CTC becomes a more accepted non-invasive examination of the colon, due to the steep learning curve of this new diagnosis method as well as the lack of formal training for the interpretation of CTC.

CAD is attractive because it has the potential to overcome this difficulty; that is, CAD has the potential to improve detection performance and reduce variability of detection accuracy among readers.

An improvement in the detection performance can be achieved because CAD can reduce perceptual errors during the detection of polyps. These perceptual errors may be caused by the presence of normal structures that mimic polyps, by fecal residuals or by variable conspicuity of polyps, depending on the display method. The absence of visual cues that normally exist with colonoscopy, such as mucosal color changes and a large number of images for each patient, also makes image interpretation tedious and susceptible to perceptual error (Bodily et al. 2005; Burling et al. 2006; Fletcher et al. 2005; Slater et al. 2006). Endoluminal 3D interpretation is also subject to observer error since 20% of the mucosa is not seen with a unidirectional fly-through (Pickhardt et al. 2006).

A reduction of variability can be achieved because CAD can provide objective and consistent results, while the performance of a radiologist may be influenced by his or her skill and experience. Moreover, a variety of circumstances, including distraction and fatigue, as well as time constraints in a busy clinical practice, influence the diagnostic performance. Although radiologists may detect a certain type of polyp in the majority of cases, the same people may miss the same type of polyp under different reading conditions. Use of CAD can potentially overcome this lack of consistency by radiologists, and thus it can be useful for reducing variability among readers in identifying polyps in CTC.

The current status of CAD on the above two issues will be described in sections 27.5 and 27.6.

### 27.3 Principles of CAD for CT Colonography

Majority of the CAD systems available today consist of the following processing units: a) digital imaging and communications in medicine (DICOM) image reader for reading CTC images from a picture archiving system (PACS) in a CAD system over a network, b) extraction of the colonic wall from the CTC images, c) detection of polyp candidates in the extracted colon, d) discrimination of false-positives from polyps among polyp candidates, and e) display of the detected polyps on the screen of a 3D workstation.

Understanding each of the processing units is essential for understanding the types of CAD pitfalls in clinical CTC cases. A summary of the key techniques for each of these units, except for the first, is provided below.