CT colonography for screening of patients at increased risk for colorectal cancer: accuracy, patient acceptance and radiation issues
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Chapter 4

Effective Radiation Doses in CT Colonography: Results of an Inventory Among Research Institutions

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Submitted
Abstract

A drawback of the potential implementation of computed tomography colonography in colorectal cancer prevention is the exposure of large populations to ionizing radiation. To estimate the magnitude of this disadvantage we performed a survey among institutions that perform research on this topic with the purpose to collect current scan protocols for estimation of the effective doses.

We found that the median dose used for CT colonography in 2004 is 5.0 mSv. For optimal sensitivity and specificity of CT colonography individuals have to be scanned in both supine and prone position, and therefore the dose must be doubled. If applied to a population aged 50, a complete (supine and prone) CT colonography examination may result in 1 fatal cancer in 4000 individuals which may become manifest after a latent period of up to a few decades. Recent studies, however, indicated that effective dose for CT colonography can be reduced substantially, thereby decreasing the attendant risks.
Introduction

At present computed tomography (CT) colonography undergoes scrutiny for its potential role in colorectal cancer prevention (1). An important consideration at this stage is the risk to induce cancer relating to the radiation exposure from large scale screening with CT. Although the increasing use of multislice scanners speeds up the examination time considerably and produces thinner slices so that eventually isotropic images are obtained, there is some loss of dose efficiency in comparison with single-slice scanners (2).

Because no recent data on the effective doses associated with CT colonography are available, no accurate estimate can be made of the potential risks of its large scale application in colorectal cancer screening. In order to assess the risks of CT colonography, we determined the effective dose associated with current scan protocols at institutions that published studies on the accuracy of this examination. In addition, we examined trends over time for various parameters of the scanning protocol and the effective dose.

Materials and Methods

Historical data from the literature We systematically searched the medical literature until 31-12-2003 using Pubmed to identify articles reporting on the accuracy of CT colonography in humans as a main or subsidiary aim. The following search terms were used: ‘virtual colonoscopy’, ‘colonography’, ‘colography’ and ‘pneumocolon’. One report per research institution was included; if more than one study was present, the study with the highest number of patients was included.

Survey The same institutions identified through the literature search were contacted to provide their current research and daily practice scan protocol to enable us to estimate their current effective dose via a questionnaire. Daily practice protocols were used in the analysis to represent the current standard.

We contacted the corresponding authors in case there were uncertainties in the current scan protocol or in the protocol described in the literature.

Estimation of effective doses The effective dose of a CT-examination is a measure of the radiation risk associated with the examination. It depends on the amount of radiation used in the examination that in its turn depends on the tube voltage (nearly
always 120 kV in the present study) and the effective mAs-level chosen by the user.

Estimates of effective dose can be obtained in different ways. We choose to use the CT Dosimetry calculator (3) because with this calculator it was possible to estimate the effective dose for all scanner types of our survey. The accuracy of the dose estimates is in the order of 20%. The dose in individual patients may differ from the dose reported here, that was determined in a mathematical phantom.

The authors of the included reports and questionnaires were informed on the estimated effective dose.

Statistical analysis

Medians, minimum, and maximum values were used to describe the central tendency and variation in effective dose and in various scanning parameters among the daily protocols of different institutions. A subgroup analysis according to the scanner technique, i.e. the number of simultaneously acquired slices (single: 1, or multi: 4, 8 or 16 slices) was performed.

Trends over time were analysed for scan parameters (effective mAs, collimation number of slices) and resulting effective doses (mSv). Time trends for mAs, collimation and effective dose were analysed by linear regression analysis using calendar year (year of publication) as the explanatory variable. The trend in the proportion of reports involving multislice scanners was analysed by the Chi-squared test for trend. The effective doses as estimated from the questionnaire data were fed back to the originating institutions, and approval on the estimated values was requested, in January 2004. This year was used to define the questionnaire (current) protocols in the trend analyses. In addition, we performed a similar analysis based on paired data from the subset of institutions for which we had both historical and current data.

Results

Literature We identified a total of 74 studies performed by 36 institutions between 1996 and 31-12-2003 reporting on the diagnostic value of CT colonography. Thirty-three out of 36 (92%) institutions provided sufficient data to estimate the effective dose and were included in our study.

Questionnaires A total of 27 (75%) institutions responded to our questionnaire sent out to 36 institutions, and provided data about their daily practice protocol.
Effective radiation doses in CT colonography

Current scan protocols and effective doses

Table 1 lists the median effective dose, slice thickness (collimation) and effective mAs values according to scanner technique as used in the present daily practice protocols. At present the median dose

Table 1. Effective doses used for CT colonography according to scanner technique in present daily practice protocols.

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>1</th>
<th>4</th>
<th>8</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>27</td>
<td>2</td>
<td>16</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Effective dose (mSv)</td>
<td>5.0 (1.2-11.7)</td>
<td>2.0 (1.4-2.6)</td>
<td>5.1 (1.2-11.7)</td>
<td>6.7 (2.7-9.9)</td>
<td>3.3 (2.6-5.8)</td>
</tr>
<tr>
<td>Effective tube charge (mAs)</td>
<td>67 (20-200)</td>
<td>54 (37-70)</td>
<td>67 (20-200)</td>
<td>84 (40-114)</td>
<td>55 (34-100)</td>
</tr>
<tr>
<td>Collimation per slice (mm)</td>
<td>2.50 (0.75-5.00)</td>
<td>5.0</td>
<td>2.50 (1.00-3.00)</td>
<td>1.9 (1.25-2.5)</td>
<td>1.13 (0.75-2.50)</td>
</tr>
</tbody>
</table>

* refers to the number of simultaneously acquired slices; 4, four slice scanner, etc. Range is indicated in parentheses.

Figure 1. Trends over time for effective doses, tube currents, slice thickness and use of multislice scanners (Literature protocols, 1998-2003; current protocols, 2004)

Effective dose remained approximately constant between 1998 and 2004 (p = 0.68). The use of mAs (p-value = 0.007) and collimation (p-value < 0.0001) decreased significantly, whereas the use of multislice scanners increased significantly (p-values < 0.0001).
that is used to scan patients in one position for CT colonography is 5.0 mSv. The median mAs value is 67 mAs with a median slice thickness of 2.5 mm. The majority of institutions (16; 59%) used four-slice scanners.

**Trends over time** The effective dose remained approximately constant (p-value =0.68) between 1998 and 2004, while both the tube current and the slice thickness decreased (p-value =0.007, p-value <0.0001, respectively), and the use of multislice scanners increased (p-value <0.0001). The paired analysis of data from the same institution (n=25) showed the same trend, but failed to reach statistical significance.

**Discussion**

The present day median effective dose for CT colonography is 5.0 mSv per CT-scan. As sensitivity and specificity are known to improve significantly when patients are scanned in supine and prone position, the majority of institutions scan patients twice, and consequently the dose doubles to 10 mSv. If applied to a population aged 50, a CT colonography examination performed in supine and prone position may result in a risk in the order of 1 fatal cancers in 4000 individuals, which may become manifest after a long latent period, possibly tens of years (4). When individuals are to be examined more than once the risk increases.

Our study demonstrated that although the use of multislice scanners increases, the effective doses that are associated with CT colonography have remained nearly constant. This is noteworthy, since the transition from single- to multislice CT has been associated with higher effective doses. The present finding may represent the fact that radiologists become increasingly aware of the feasibility of low dose scanning for CT colonography, as reflected by the decreased median mAs values over time.

We note that there is mounting evidence that CT colonography can be performed with effective doses below 1 mSv for a complete examination (5,6) and several institutions appeared to use doses of this magnitude at present. Because a reduction of effective dose results in a proportional reduction of risk, the use of such low doses may substantially diminish this drawback.
References

2. Kalender W. Computed Tomography. Publicis MCD Verlag, 2000; 130-131