Assessing Polyp Size by Improved Digitalized Computed Tomography (CT)

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Abstract. *Background: The size of colorectal polyps is important in the clinical management of these lesions. When using a conventional ruler (the tool of pathologists worldwide), we have previously found unacceptably high intra- and inter-observer variations in assessing the size of phantom polyps. The aim of this study was to assess the size of 12 phantom polyps by computed tomography (CT). Materials and Methods: The size of phantom polyps as assessed by CT was compared to the gold standard size (GSS) measured at The Royal Institute of Technology, Stockholm, Sweden. Results: In 33.3% (n=4) of the 12 polyps and in 41.7% (n=25) of the 60 measurements, the mean CT size under- or overestimated the GSS by more than 1 mm. In 15%, or in 9 of the 60 measurements, the CT size was under- or overestimated by more than 2 mm. In polyp #5 the GSS size was 8.41 mm where the expected cancer-risk in adenomas is 1%. But 3 out of 5 CT measurements were >10 mm, where the expected cancer-risk in adenomas is 10%. In polyp #10 the GSS size was 10.20 mm where the expected cancer-risk is 10%. But 2 out of 5 CT measurements were <10 mm where the expected risk is only 1%. Conclusion: The size assessed by CT was more reliable than that obtained with a millimetre ruler using the same devices, inasmuch as the disparate individual deviation-values found with the latter method were avoided. The volume and the shape of the devices influenced size assessment of phantom polyps by CT.*

In 1887, Esmarch postulated the notion that colorectal adenomas had a malignant potential (1). Forty years later, Feyter (2) confirmed the claims of Esmarch (1). Today we know that adenomas may antedate invasive carcinomas (3, 4).

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In 1973, three pathologists from St Marks Hospital in London demonstrated that the risk for histologically confirmed colorectal adenoma to evolve into an invasive carcinoma correlated with the size of the adenoma. For lesions under 1 cm in diameter the cancer risk was about 1%, for those between 1 and 2 cm in diameter 10%, and for those measuring over 2 cm, the cancer risk was nearly 50% (4).

Radiologists (5-10), endoscopists (11-20) and other pathologists (21, 22) subsequently accepted the size-limits proposed by those pathologists to estimate polyps at risk (4).

Radiologists estimate the size in barium contrast, in double-contrast radiography and in multi-detector Computed Tomography (CT) colonography. With the latter method, Vogt *et al*. detected colorectal polyps 5 mm or greater in size (6). However, in a systematic review and meta-analysis, Halligan *et al*. (7) pooled reports on the performance of CT colonography and found for category 1 polyps (≤5 mm in diameter) that the average sensitivity was 77% while for category 2 polyps (6 to 9 mm in diameter) it was 70%. Category 3 polyps (≥10 mm in diameter) were not included in the meta-analysis because of the large amount of heterogeneity in sensitivity, specificity and overall performance in the reports. Thus, radiology, even when applying modern techniques of observation, seems to be inadequate for measuring the size of colorectal polyps with accuracy.

More recently, Park *et al*. (8) compared the polyp size as measured using optical colonoscopy with that using CT colonography in pig colonic specimens. These authors studied 18 manufactured polyps prepared from fresh pig colons. Five simulated sessile polyps were sutured into the mucosa of inverted colons. The polyp size varied between 5 and 10 mm or larger, as measured with a ruler and a bore gauge. After optical colonoscopy, the colonic specimen was inverted inside-out and polyps were re-measured by a ruler and a bore gauge. Four polyps that showed size differences between the initial measurement and the re-measurement were excluded. Using this

method, the authors postulated that CT colonography was more reliable and accurate than optical colonoscopy for polyp measurement.

Endoscopists use the distance between open biopsy forceps as a reference to estimate the size of colorectal polyps. Some endoscopists assert that distance to be 6 mm apart (15) and others 8 mm (17). The National Polyp Study Work Group (14) use the size estimated by the endoscopist to classify polyps into the 3 groups suggested by pathologists (4). More recently, eight experienced endoscopists estimated the size of artificial polyps. The average size recorded by experienced endoscopists was adopted as a gold standard. The eight experienced endoscopists found that the measuring of colonic polyps at endoscopy by the "eye ball" method was unacceptable low, namely 35% (18).

Pathologists measure the size of endoscopically removed polyps with a conventional millimetre ruler. It has been claimed that these measurements are preferable to endoscopical estimates (23). Recently, however, a group of 22 experienced pathologists and surgeons measured the size of phantom polyps with a conventional millimetre ruler (24). The results of two independent measurements were compared with the gold standard size as assessed at the Department of Production Engineering, The Royal Institute of Technology, in Stockholm. The results showed a high intra- and inter-observer variation in assessing the size of the phantom polyps. The volume and the shape of devices, as well as a human error in reading the scale of the ruler were confounding factors in size assessment.

The purpose of the present work was to explore whether an improved CT technique could assess the true size of the same phantom polyps used in a previous work (24). The method applied here differs from those reported by others (21-23) inasmuch as the results of CT measurements were compared to the gold standard size of the phantom polyps as assessed at the Department of Production Engineering, The Royal Institute of Technology (24).

Materials and Methods

Twelve artificial papier-mâché polyps were painted with a colour and varnished (Figure 1). The devices were placed in individual vials labelled #1 to #12.

Measurements done at The Royal Institute of Technology. The method used was reported elsewhere (24). Measurements of the 12 phantom polyps were made by low force contact metrology, at a temperature of 20˚C ± 1˚C. Held between the fingertips, each artificial polyp was rotated in a gap between two parallel metal surfaces of a micrometer screw. The distance between the surfaces was reduced until the largest diameter of the polyp caused slight friction when turned around in the gap. A measurement series was performed in random order among the 12 artificial devices. The micrometer screw (Mitutoyo Digimatic MDC-25MJT) has a certified uncertainty of 0.0016 mm. Only the polyp with the largest diameter was measured with a calliper, as its size exceeded the micrometer screw measurement range. The Luna calliper has 0.1 mm uncertainty. The procedure was repeated every second day and after 5 measurements, the average and standard deviations for each sample was calculated. It is worth noting that the contact low friction technique applied in this study cannot be used for soft devices. In such cases, non-contact optical techniques would be preferred. The limitations of such a procedure are the high number of projections required to determine the maximum diameter.

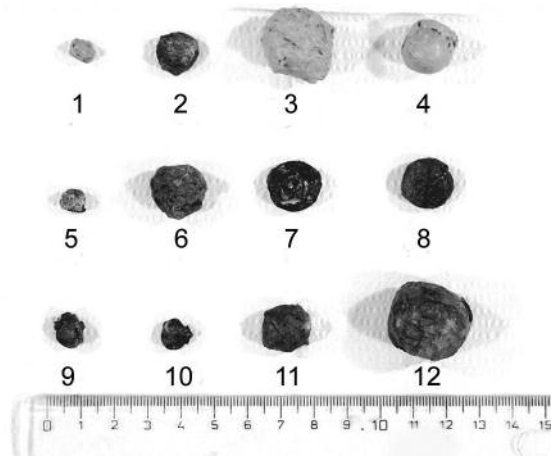

Figure 1. *The 12 phantom polyps used for CT measurements. These were subsequently measured at The Royal Institute of Technology, the largest diameter obtained being regarded as the gold standard.*

Measurements carried out at the Department of Diagnostic Radiology. CT was performed with a 4-detector row CT scanner (Light Speed Qx/i, GE Medical Systems, Milwaukee, WI, USA) with the following parameters: tube voltage, 80 kV; tube current 40 mAs; beam collimation, 4 detector rows with 3.75 mm table speed; 0.75-mm helical pitch; reconstructed section thickness, 1.25 mm; scanning field of view (sFOV) 50.0 cm.

All images were sent to a workstation (Advantage Workstation AW4.1-06; GE Medical Systems) where three-dimensional (3D) measurements were obtained with the following display parameters: display FOV 9.6 cm; matrix 512×512. Window width and window level were set at 1600 HU (Hounsfield unit) and - 450 HU.

A radiologist (C.S.) reviewed all images and measured the longest diameter using an electric calliper. Five independent measurements were made, blind to the gold standard size assessed previously at the Royal Institute of Technology.

Results

Measurements at the Department of Production Engineering, The Royal Institute of Technology. The results of the measurements made at the Department of Production Engineering are shown in Table I, which shows that the standard deviation for measurements of the largest diameter in the 12 devices was ≤0.05 mm, significantly less than when using the micrometer screw and ≤0.3 mm for the calliper ($p<0.3$).

Table I. *The size of 12 phantoms polyps. Measurements were carried out at the Department of Production Engineering at The Royal Institute of Technology, Stockholm, Sweden.*

Sample	1	2	3	4	5	6	7	8	9	10	11	12
Average (mm)	8.52	13.39	24.80	18.68	8.41	18.86	16.80	16.33	10.99	10.20	16.58	27.7
SD (mm)	0.03	0.04	0.05	0.04	0.05	0.05	0.01	0.02	0.05	0.03	0.03	0.3
Range (mm) max–min	0.07	0.09	0.09	0.07	0.09	0.09	0.03	0.04	0.11	0.06	0.06	0.5
Min	8.48	13.34	24.76	18.65	8.35	18.81	16.79	16.31	10.93	10.17	16.54	27.4
Max	8.55	13.43	24.85	18.72	8.44	18.90	16.81	16.35	11.04	10.23	16.60	27.9
Difference of the range	0.07	0.09	0.09	0.07	0.09	0.09	0.02	0.04	0.11	0.06	0.06	0.05

Measurements at the Department of Diagnostic Radiology. Table II shows the mean size of the devices in individual measurements, carried out on 5 different occasions.

The Table shows that the mean of CT value varied between 9.46 mm (polyp #1) and 24.66 mm (polyp #12). The largest range between maximum and minimum values on 5 different occasions was 0.8 mm in polyp #9 and 3.4 mm in polyp #3. The range in these 2 phantom polyps was significantly higher than those recorded in the same polyps with the micrometer screw ($p<0.05$).

The smallest standard deviation was 0.35 mm in polyp #9 and the largest, 1.38 mm in polyp #3, standard deviations that were significantly higher than those recorded in the same polyps with the micrometer screw ($p<0.05$).

Comparison between measurements made at the Department of Diagnostic Radiology and at The Royal Institute of Technology. Table II shows that the mean CT size was under- or overestimated in all 12 polyps when compared to the gold standard size (GSS) (Table II). Mean CT values under- or overestimated the gold standard by more than 1 mm in 33.3%, or in 4 of the 12 polyps. In polyp #12, the error was –3.04 mm. In the remaining 8 polyps (66.7%) CT values were only a fraction of mm from the standard size.

The results showed that in 41.7%, or in 25 of the 60 measurements, the CT size under- or overestimated the gold standard size by more than 1 mm. In 15%, or in 9 of the 60 measurements, the CT size was under- or overestimated by more than 2 mm (up to 4 mm in polyp #12). In the remaining 35 measurements (58.3%), CT values were only a fraction of mm from the standard size (Table II).

Table II. *The mean values of 5 separate blind CT measurements, of the 12 phantoms polyps.*

	Measurements (mm)					
"Polyp"#	1st	2nd	3rd	4th	5th	Mean size (mm)
1	9.7	9.4	8.7	9.2	10.3	9.46
2	14.4	13.7	15.0	13.5	13.3	13.98
3	25.3	23.5	22.4	22.3	21.9	23.08
4	18.4	17.4	17.7	18.6	17.7	17.96
5	9.1	10.1	9.0	10.3	11.1	9.92
6	17.9	17.4	16.9	16.7	17.3	17.24
7	16.4	18.5	16.5	16.4	16.6	16.88
8	17.1	17.6	17.3	15.4	16.0	16.68
9	10.9	10.8	10.5	10.1	10.2	10.50
10	9.7	10.5	9.4	10.3	10.3	10.04
11	16.4	17.0	15.5	16.1	15.6	16.12
12	24.9	26.0	24.1	24.6	23.7	24.66
Mean size (mm)	15.85	15.99	15.25	15.29	15.33	15.54
Range (mm)	9.1-24.9	9.4-26.0	8.7-24.1	9.2-24.6	10.2-23.7	9.46-24.66

Discussion

In a previous work (24), 22 pathologists and surgeons measured the same 12 devices used here in two separate blind trials using a conventional millimetre ruler, the tool used in routine procedures by pathologists, worldwide. In the first trial, all 264 measurements were under- or overestimated, in 33.3% (88/264) by more than 1 mm. The maximal overestimated size was + 1.48 mm and the maximal underestimated size was – 6.86 mm. In the second

trial, all 264 measurements were also under- or overestimated, in 33.3% (88/264) again by more than 1 mm. The maximal overestimated size was +3.70 mm and the maximal underestimated size was –7.80 mm. In the remaining 66.7% in both trials, the deviation from the gold standard size was only a fraction of mm. The conclusions from that work (24) were that the volume and the shape of the devices had influenced the results; phantom polyps of a large volume and/or with an irregular uneven shape were more difficult to measure with a ruler than phantom polyps of a small volume or with a regular smooth shape. The highly under- or overestimated values given in some measurements by individual workers were regarded as human error in reading the scale on the ruler, most likely due to lack of mental concentration during the task, or to personal fatigue.

The present results using CT, unexpectedly mimicked those obtained by a conventional ruler, inasmuch as 33.3% of all measurements were under - or overestimated by the CT, and by the millimetre ruler readings (24). However, the highly disparate values provided by some observers when using the conventional ruler (24), were not recorded when measurements were made with CT.

The volume of the devices influenced CT measurements, as polyps with a large volume (#3 and #12 in Figure 1) were more difficult to measure with CT than those with a small volume (#1, #2, #9 and #10 in Figure 1). CT often underestimated the size of large polyps. The size of polyps of moderate volume (#4, #6, #7, #8, and #11 in Figure 1) was often underestimated by CT, by up to (24) - 1.62 mm in polyp #6. Paradoxically, polyps #4 and #6, having about the same size (cfr. Figure 1) were regarded differently by CT. In fact, CT underestimated the size of polyp #4 by only - 0.72 mm and of polyp #6 by as much as - 1.62 mm. The irregular shape of polyp #6 when compared to that of the more regular polyp #4 (in Figure 1), seems to have contributed to this difference.

According to today's accepted size risk-limits for colorectal adenomas (4), to wrongly size an adenoma by >1 mm may have far reaching clinical consequences. If an adenomatous polyp measures ≤9 mm, the expected cancer risk is only 1%, but if it is measured as being 10-19 mm, the expected cancer risk is 10% (4). An example from our results: according to the gold standard, the largest diameter in polyp #5 was 8.41 mm (Tables I and II) where the expected risk is 1%. But 3 of 5 CT measurements were >10 mm, where the expected risk is 10%. As another example: according to the gold standard, the largest diameter in polyp #10 was 10.20 mm (Tables I and II) where the expected risk is 10%. But 2 of 5 CT measurements were 9 mm where the expected risk is only 1% (4).

In conclusion, the volume and the shape of the devices influenced the size assessment of phantom polyps by CT; polyps of a large volume and/or with an irregular uneven shape, were more difficult to measure by CT than those of a small volume or with a regular smooth shape.

CT values were somewhat more reliable than those obtained with a conventional millimetre ruler (used by pathologists), inasmuch as the disparate deviation values found with the latter method while reading the scale on the ruler (probably conveyed by lack of concentration with the task or by personal fatigue) were avoided.

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