Measurement of polyp size at colonoscopy: a proof of concept simulation study to address technology bias

Shinichiro Sakata, MBBS\textsuperscript{1,2,3}, Felicity McIvor, MBBS\textsuperscript{3}, Kerenaftali Klein, PhD\textsuperscript{4}, Andrew R. L. Stevenson, MBBS, FRACS\textsuperscript{1,2}, and David G. Hewett, MBBS, MSc, PhD, FRACP\textsuperscript{1,3}

\textsuperscript{1}School of Medicine, The University of Queensland; 
\textsuperscript{2}Department of Colon and Rectal Surgery, Royal Brisbane & Women’s Hospital; 
\textsuperscript{3}Division of Gastroenterology, The Queen Elizabeth II Jubilee Hospital; 
\textsuperscript{4}Clinical Trials and Biostatistics Unit, QIMR Berghofer Medical Research Institute; All in Brisbane, Australia.

SUPPLEMENTARY METHODS

Participants
Endoscopists from the Asian Narrow Band Imaging Group and The Australian New Zealand Endoscopy Leaders Forum, both international academic interest groups of expert endoscopists, were invited to complete this study via an online platform. Participants performed the study individually on their personal computers. We used a proportion test to determine that a sample size of 50 participants was required to achieve power of 95%. Therefore, the first 50 responding endoscopists participated in the study.

Test items
We assembled an image library of simulated polyps taken with an Olympus CF-HQ190L colonoscope (Olympus Corporation, Tokyo, Japan). The simulated polyps were made from steel hemispheres and were of 10 exact sizes (1-10mm, American Bearing Manufacturers Association diametrical tolerance +/- 0.01270 mm). Forty simulated polyps were prepared, comprising 10 sizes (1-10mm) positioned at two viewing distances (10mm and 20mm) and two display image locations (centre and periphery of the display image). The 40 polyps were photographed under three measurement conditions or strategies: (a) Method 1: no visual cues, in which the polyp was photographed against a plain, orange background without any frame of reference; (b) Method 2: a snare tip visual cue, in which the polyp was photographed against the same orange background, but the 2.4mm diameter tip of a snare catheter was added to centre of the display (Exacto, US Endoscopy, Mentor, OH), and (c) Method 3: a measurement grid visual cue, in which the polyps were photographed against a 1x1mm measurement grid (Figure 2). The colonoscope viewing distances were measured with a straight ruler and controlled with a clamp, and viewing distances were repeatedly confirmed before and after each polyp photograph was taken.
Procedure

Endoscopists were presented images of the 40 simulated polyps under the three measurement conditions; a total of 120 polyp images. The images were presented via an online testing platform, accessed via individual logins generated by each participant. For each measurement condition, participants were told they were viewing simulated polyps on simulated colonic mucosa, and given an exemplar image with arrows demonstrating the outer margin of the polyp that should be used for measurement. Participants were instructed that simulated polyp images were photographed with an Olympus CF-HQ190L colonoscope. Participants were also instructed to regard all images of simulated polyps as actual polyps detected during colonoscopy. They were instructed that each polyp was between 1 and 20mm in size. To limit expectation bias, participants were told to assess each polyp individually and that multiple polyps of the same size may be present and that some sizes may not have been included.

Endoscopists were informed that the snare tip measured 2.4mm, and that the measurement grid measured 1x1mm. To avoid learning confounds from the measurement grid method, the measurement conditions were presented in the same order: no visual cues, then the snare tip visual cue, and last the measurement grid visual cue. Within each measurement strategy, the 40 polyps were presented in a random order unique to each endoscopist. For each polyp, participants had to select a polyp size as a whole number in millimetre increments (from 1 to 20mm), and their level of confidence (high or low) that the polyp was diminutive (1-5mm), small (6-9mm) or large (≥10mm in size) in size. Once each polyp had been scored, participants were not able to change their response or start the test again.

We also collected information from participants about their practice setting (academic hospital, community hospital, private practice or ‘other’) and their level of experience in colonoscopy (101-1000 colonoscopies, 1001-5000 colonoscopies, 5001-10,000 colonoscopies or more than 10,000 colonoscopies).

Study measures

The primary outcomes were accuracy of polyp size measurements using the three measurement strategies. We measured exact accuracy, corrected accuracy (+/- 1mm), and accuracy by size category (correctly identifying polyps as diminutive 1-5mm, small 6-9mm or large ≥10mm in size). For each polyp measured, we assessed the participant’s confidence in their chosen size category (confident versus not confident). Measurement bias, precision and predictors of measurement accuracy were secondary outcome measures. Data management and analyses, including a stepwise covariate selection method and mixed effects logistic regression, were performed in R, version 3.2.0.
SUPPLEMENTARY RESULTS

Participants
Of the 50 endoscopists, 42 (84.0%) completed all 120 simulated polyp measurements. Of the 50 participants, 35 (70%) worked primarily in academic hospitals, 9 (18%) in community hospitals, 3 (6%) in private practice and 3 (6%) worked in other settings. Regarding their post-fellowship experience in colonoscopy, 2 (4%) reported to have performed 101-1000 colonoscopies, 18 (36%) reported to have performed 1001-5000 colonoscopies, 14 (28%) reported to have performed 5001-10000 colonoscopies and 16 (32%) reported to have performed more than 10000 colonoscopies.

Accuracy and confidence of measurements
The measurement accuracies using Method 1 (no visual cues), Method 2 (a 2.4mm snare tip visual cue), and Method 3 (a 1x1mm measurement grid visual cue), were 20%, 33% and 90% respectively (Table 1); accuracies between each of these methods were significantly different (p < 0.001). Endoscopists were 71% confident, 80% confident and 95% confident using Methods 1, 2 and 3 respectively (p < 0.001). For measurements made with high confidence, the accuracies of correctly classifying each polyp as diminutive, small or large were 66.7% (using Method 1), 75.7% (using Method 2) and 99.6% (using Method 3) respectively (p < 0.001).

Table 1 also shows the measurement accuracies for simulated polyps presented at the centre of the display image and at the periphery of the display image. Although there was no significant difference in accuracy between polyp positions for Methods 1 and 3, measurements using the snare tip (Method 2) were significantly more accurate when the polyp was in the centre of the screen (accuracy 39%), than in the periphery (accuracy 26%, p < 0.001).

There was no significant difference in measurement accuracy between levels of confidence of measurement, endoscopists with different levels of experience or the endoscopist’s practice setting.

Predictors of accuracy
Although the accuracies produced using Methods 1 and 2 were low, these methods are commonly used during real-time colonoscopy. Hence, we performed a mixed effects logistic regression analysis to evaluate predictors of accuracy when Methods 1 and 2 were used.

In Methods 1 and 2, the true size of a polyp was inversely associated with the accuracy of measurement. For both methods, a 1mm increase in the true size was associated with a 35% decrease in the odds in measuring a polyp accurately (OR: 0.65, 95% CI: 0.66, 0.66, p < 0.001).
In Method 1, in which no measuring cues were used, image location and viewing distance did not significantly affect measurement accuracy when a visual cue was not present. In Method 2, in which the snare tip was present to allow relative comparisons between it and the polyp, polyps located at the edge of the photo (and away from the snare tip visual cue) had a 55% decreased chance in being measured correctly compared to the polyps located at the centre and adjacent to the snare tip (OR: 0.45, (95% CI: 0.45, 0.45) p < 0.001). Polyps located at a viewing distance of 20mm had a 30% decreased chance in being measured correctly than polyps at a viewing distance of 10mm (OR: 0.70, (95% CI: 0.69, 0.70), p< 0.003).

In all methods, there was no significant association between accuracy of measurement and the confidence of estimates, the experience of endoscopists, or the participant’s practice setting.

**Bias and Precision**

Supplementary figure 1 shows box plots of polyp measurements against the true size of polyps for each measurement condition (Methods 1, 2 and 3). Using Methods 1 and 2, there was wide variation in endoscopists’ measurements, although in general, they overestimated the size of diminutive polyps and underestimated the size of small polyps. There was minimal variation with Method 3. Methods 1 and 2 generated significantly biased estimates (p-values: < 0.001 and 0.003 respectively). The precision of estimates generated using Method 3 was approximately 50 fold greater than those of Method 1 and Method 2.

Supplementary figure 2 shows density plots of polyp measurements against true polyp sizes for Method 1 and 2 overlaid with the true density. Even though the true density of polyp sizes was uniform across the size range, endoscopists using Method 1 and 2 produced more diminutive measurements and less small measurements.
SUPPLEMENTARY FIGURE 1.
Box plots of estimated polyp sizes (y axis) by true polyp sizes (x axis).

SUPPLEMENTARY FIGURE 2.
Density distributions of measurements (y axis) against true polyp size (x axis). True density compared with estimated density by method of polyp measurement. Method 1: no visual cue, Method 2: snare tip visual cue, and Method 3: measurement grid. The true density is a flat line, because the polyp sizes were evenly distributed across the 1-10mm range. Vertical line at 5.5mm, separating diminutive and small polyp sizes. The estimated density plots suggest that the majority of 6-10mm polyps are considered diminutive.