Original Investigation

"Rounding" the Size of Pulmonary Nodules: Impact of Rounding Methods on Nodule Management, as Defined by the 2017 Fleischner Society Guidelines

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Rationale and Objectives: The objective of this study was to quantify the impact of different rounding methods on size measurements of pulmonary nodules and to determine the number of nodules that change management categories as a result of rounding.

Materials and Methods: For this retrospective institutional review board-approved study, we included 503 incidental pulmonary nodules (308 solid and 195 subsolid) from a data repository. Long and short axes were measured. Average diameters were calculated using four different rounding methods (method 1: no rounding; method 2: rounding only the average diameter to the closest millimeter; method 3: rounding only short and long axes; and method 4: rounding short and long axes and the average diameter to the closest millimeter). Nodules were classified for each rounding method according to the 2017 Fleischner Society guideline management categories. Measurements were compared among the four rounding methods using analysis of variance.

Results: Without rounding, the average nodule diameter was 15.67 ± 5.97 mm. This increased between 0.03 and 0.29 mm using rounding methods 2–4 (range: $P < 0.001$–0.017). The nodule size was more frequently rounded up (range: 52.1%–77.5%) than rounded down (range: 17.7%–42.5%) using rounding methods 2–4, as compared to no rounding. In the 308 solid nodules, up to 2.9% of the nodules changed management category, whereas none of the 195 subsolid nodules changed category.

Conclusions: Rounding methods have a small absolute but statically significant effect on nodule size, impacting management category in less than 3% of the nodules. This suggests that, in clinical practice, any rounding method can be used for determining nodule size without substantially biasing individual nodules toward given management categories.

Key Words: Lung nodules; lung adenocarcinoma; computed tomography; rounding; Fleischner Society guidelines.

INTRODUCTION

"Rounding" refers to the replacement of a number by another number of approximately the same value, but which is shorter and simpler to use (1). The newly published 2017 Fleischner Society guidelines for the management of pulmonary nodules recommend expressing nodule size "rounded" to the nearest millimeter (2). There are, however, different possible approaches to rounding the size of pulmonary nodules (3), but the guidelines are not explicit as to which of these approaches should be used.

Only one previous study has assessed the impact of rounding on size measurements in pulmonary nodules (3). Li et al.'s study was conducted in the context of computed tomography (CT) lung cancer screening and focused on the longitudinal evolution of nodule size (3). No previous study has investigated the influence of rounding on nodule size measurements in the context of managing incidentally detected pulmonary nodules, as described in the newly published 2017 Fleischner Society guidelines (2). Therefore, the purpose of our study was to quantify the impact of different rounding methods on size measurements of pulmonary nodules and to determine the number of nodules that change management categories as a result of rounding.

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MATERIALS AND METHODS

Study Material

The study protocol was approved by our institutional review board and informed consent was waived (protocol no. 15–020). The 503 pulmonary nodules on which the current study was based were part of our hospital's data repository of pathologically confirmed resected pulmonary adenocarcinomas. This data repository served for other studies on different topics, with a partial overlap of lesions and patients (4–7). Inclusion and exclusion criteria of nodules had been previously published (4).

CT Acquisition

Given that the CT data were acquired over our entire hospital network, various CT scanner units and acquisition protocols were used. However, all CT units were considered state of the art at the time of acquisition. Most frequently, Aquilion One (320-detector row unit; Toshiba, Otawara, Japan), Discovery CT750 HD (64-detector row unit; GE Medical Systems, Milwaukee, WI), and LightSpeed VCT (64-detector row unit, GE Medical Systems) were used. All CT examinations were acquired in a supine body position, at total lung capacity, and over the entire thorax. Before April 2007, CT examinations were performed with a fixed milliampere-second (range: 200–400 mAs) and 120 kVp. After April 2007, the examinations were performed using automated exposure control and other dose reduction algorithms. All images were reconstructed with thin sections using high spatial frequency algorithms in lung window settings (mean, −500 HU; width, 1500 HU). Only images reconstructed in the transverse plane were used in the present study. A total of 210 (41.7%) examinations were performed for staging purposes with intravenous contrast material administration, whereas in the remaining 293 examinations (58.3%), no contrast material was administered.

Patient Population

Of the 503 nodules included in the study, 308 nodules (61.2%) were solid and 195 nodules (38.8%) were subsolid. Most nodules were located in the right upper and left upper lobes (189/503, 37.6%, and 128/503, 25.4%, respectively). Of the 503 nodules, 80 (15.9%) were located in the right lower lobe, 74 (14.7%) were located in the left lower lobe, and 32 (6.3%) were located in the right middle lobe.

The mean age of the patients in whom these nodules were found was 68 ± 9 years (range: 42–89 years). Of the 503 patients with lung nodules, 305 (60.6%) were women (mean age, 68 ± 9 years; range: 42–89 years) and 198 (39.4%) were men (mean age, 68 ± 9 years; range: 47–86 years). No statistically significant difference in age was found between women and men ($P = 0.834$).

Nodule Measurements

All nodules were displayed on our picture archiving and communication system (Centricity, GE Healthcare, Milwaukee, WI), and the diameters were measured by one observer (A.A.B., with 20 years of experience). All nodules were measured in lung window settings on images reconstructed using high spatial frequency algorithms on the transverse CT section displaying the largest nodule dimensions. First, the long-axis diameter was measured. Then, perpendicular to the long-axis diameter, the short-axis diameter was measured. Long- and short-axis diameters differed in 495 of the 503 nodules (98.4%). We, therefore, measured both the long-axis and the short-axis diameters for each nodule. All diameters were measured in millimeters with a 0.1-mm magnitude, as provided by our picture archiving and communication system, and entered into a computer spreadsheet.

Statistical Analysis

Based on long- and short-axis diameters, the following four methods were used to calculate the average nodule size:

- Method 1: no rounding—the average nodule diameter was calculated without rounding of the long- and short-axis diameters, or of the average diameter.
- Method 2: only the calculated average diameter was rounded to the closest millimeter.
- Method 3: both long- and short-axis diameters were rounded to the closest millimeter before calculating the average diameter, but without rounding the average diameter.
- Method 4: the average diameter was determined as described in method 3 and then rounded to the closest millimeter.

All of these rounding methods were previously used for assessing the size of pulmonary nodules (3).

As a first step, we calculated the average nodule diameter according to the four rounding methods described previously. For each rounding method, the means of the average nodule diameter were computed. To display possible small differences between the methods, computed means were expressed with a 0.01-mm magnitude, as provided by our statistical program and as recommend in the mathematical literature (8). Differences among the four rounding methods in all nodules, solid nodules, and subsolid nodules were assessed for statistical significance using analysis of variance for repeated measurements, with individual differences assessed with Šidák-corrected paired *t* tests (9).

As a second step, to display differences between no rounding and rounding methods 2–4, Bland-Altman plots were generated (10).

As a third step, to assess the range of these differences, we identified the maximal increase and the maximal decrease in nodule size.