

# Measuring Stone Surface Area from a Radiographic Image Is Accurate and Reproducible with the Help of an Imaging Program

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## Abstract

**Background and Purpose:** The surface area of the stone from a radiographic image is one of the more suitable parameters defining stone bulk. The widely accepted method of measuring stone surface area is to count the number of square millimeters enclosed within a tracing of the stone outline on graph paper. This method is time consuming and cumbersome with potential for human error, especially when multiple measurements are needed. The purpose of this study was to evaluate the accuracy, efficiency, and reproducibility of a commercially available imaging program, Adobe Photoshop® 7.0 for the measurement of stone surface area.

**Materials and Methods:** The instructions to calculate area using the software are simple and easy in a Windows-based format. The accuracy of the imaging software was estimated by measuring surface areas of shapes of known mathematical areas. The efficiency and reproducibility were then evaluated from radiographs of 20 persons with radiopaque upper-tract urinary stones. The surface areas of stone images were measured using both graph paper and imaging software. Measurements were repeated after 10 days to assess the reproducibility of the techniques. The time taken to measure the area by the two methods was also assessed separately.

**Results:** The accuracy of the imaging software was estimated to be 98.7%. The correlation coefficient between the two methods was  $R^2 = 0.97$ . The mean percentage variation using the imaging software was 0.68%, while it was 6.36% with the graph paper. The mean time taken to measure using the image analyzer and graph paper was  $1.9 \pm 0.8$  minutes and  $4.5 \pm 1.08$  minutes, respectively ( $P < 0.001$ )

**Conclusion:** The imaging program is accurate, fast, and highly reproducible in estimating two-dimensional stone surface area from radiographs compared with manual measurements using graph paper.

## Introduction

A VARIETY OF THERAPEUTIC MODALITIES are available for the management of upper urinary tract stones.<sup>1</sup> To decide on a modality of treatment, an accurate assessment of stone burden is essential.<sup>2</sup> Stone length and two-dimensional surface area measured from a radiographic image are parameters commonly used to measure stone bulk. These dimensions do not accurately measure stone mass, but studies have confirmed that two-dimensional stone surface area is more representative of stone volume compared with stone length.<sup>3,4</sup>

Reporting treatment outcomes based on stone size will be more precise if size is determined as surface area. The com-

monly used method is to trace the stone outline onto graph paper, followed by counting manually the number of square millimeters within it. Counting diligently the number of squares from graph paper can be cumbersome, with potential for human error. We studied a commonly available imaging program, Adobe Photoshop® 7.0 (Adobe Systems Inc., San Jose, CA), for the measurement of stone surface area.

## Materials and Methods

The accuracy of the imaging program was examined by measuring the surface area of 20 shapes of known surface area (rectangle, square, triangle, and circle) drawn on paper, using the imaging software and comparing them with actual

areas estimated by respective formulas: (rectangle = length  $\times$  breadth, square = length<sup>2</sup>, circle =  $\pi \times$  radius<sup>2</sup>, triangle =  $0.5 \times$  height  $\times$  base).

We then tested the effectiveness and reproducibility of the image-analyzing program and graph paper in measuring stone surface area from radiographic images of the kidneys, ureters, and bladder of 20 persons with radiopaque upper-tract urinary stones. There were five staghorn stones, nine pelvic stones, nine caliceal stones, and three upper ureteral stones. There were multiple stones in four kidneys.

One observer made measurements using graph paper on all the stones twice, with the second measurement separated by a few days. Another observer used the imaging software to measure the same stone images also on two occasions separated by 10 days. Correlating measurements made using both methods tested the effectiveness. Estimating percentage variation in measurements by observers using the same method at different occasions assessed reproducibility. A separate assessment was also made of the mean time taken to count the surface area after the image has been imported to the graph paper and image analyzer by a single observer of 10 renal stone radiographs.

The imaging program provides the area of stones in pixels. Pixel is the smallest unit in a digital image. The number of pixels in an image defines its size. This area in pixels can be converted to square millimeters (mm<sup>2</sup>) by standardizing the pixels to millimeters from a measuring ruler kept alongside the radiograph. The area in mm<sup>2</sup> is calculated by the formula: Area in mm<sup>2</sup> = (area in pixels)/(pixel length of 1 mm)<sup>2</sup>. The two-dimensional stone surface areas using the imaging program ranged from 74 mm<sup>2</sup> to 1215 mm<sup>2</sup> (mean 452 mm<sup>2</sup>).

The image of the radiograph alongside a transparent measuring ruler is captured using a digital camera (Fig. 1). The file is opened in Adobe Photoshop® 7.0. The unit of measurement is set for pixels in the Units & Rulers preferences dialog box (Edit > Preferences > Units & Rulers). Make sure that the "Use Cache for Histograms" option is deselected (Files > Preferences > Memory & Image Cache). The Polygonal lasso tool is used to trace around the margin of the stone.



FIG. 1. The image with a ruler opened in Adobe Photoshop®.

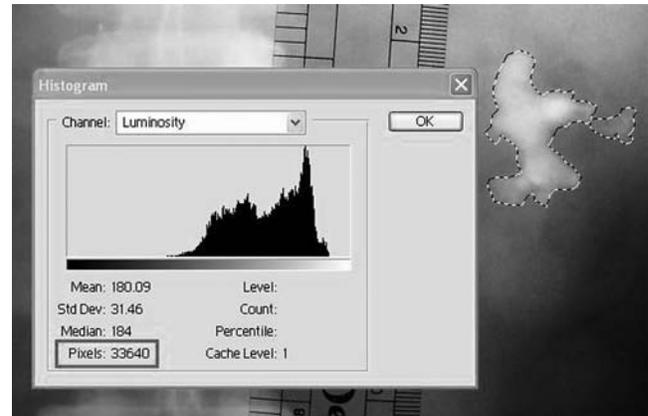


FIG. 2. The stone image lassoed and the area in pixels (A) noted in the histogram box (A = 33640).

To measure multiple areas (multiple stones), the first measurement is made as described and the Shift key held down to repeat the process for the other stones. The pixel area of the selection (stone) is given in the value of pixels (left lower corner) in the Histogram dialog box (Image > Histogram) (Fig. 2).

The measuring tool in the Photoshop tools bar is activated, and the cursor is dragged while holding down the mouse button along the ruler image for 1 cm. The D (distance) value given in the right upper corner of the Info Palette (Window > Info) corresponds to the pixel length of 1 cm (10 mm) (Fig. 3). The stone surface area in mm<sup>2</sup> is derived from the equation: Area in mm<sup>2</sup> = (area in pixels)/(pixel length of 1 mm)<sup>2</sup>. The data are imported to a Microsoft Excel sheet for easy calculation of multiple values by incorporating the formula in a cell.

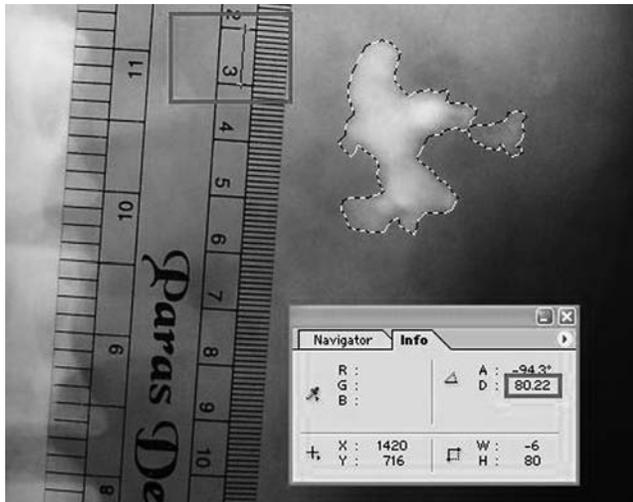
## Results

Accuracy of the imaging program was a high 98.7%, determined by measuring surface areas of shapes of known areas. There was good correlation between the two methods ( $R^2 = 0.97$ ). The reproducibility, calculated as the mean percentage variation, using the imaging program was 0.68%, while using graph paper was 6.36% ( $P = 0.01$ ). There were seven stones with an area smaller than 300 mm<sup>2</sup> and 13 stones with an area larger than 300 mm<sup>2</sup>. Reproducibility of the graph paper method was worse with larger stones compared with smaller stones (7.05% *v* 5.08%). The reproducibility of the image analyzer technique got better as the size of the stone increased (0.51% *v* 1.0%).

The mean time taken to measure the surface area in a separate analysis by a single operator for 10 stone images (mean surface area of  $605 \pm 174$  mm<sup>2</sup>) using the image analyzer and graph paper was  $1.9 \pm 0.8$  minutes and  $4.5 \pm 1.08$  minutes, respectively ( $P < 0.001$ ).

## Discussion

This technique of measuring stone surface area using the imaging program may be useful for purposes of stone research—for example, more accurately determining stone burden between treatment groups. Stone bulk is an impor-



**FIG. 3.** One centimeter in the ruler image converted to pixels (D) in the info palette. Then  $1 \text{ mm} = D/10$  pixels, so stone area in  $\text{mm}^2 = A/(D/10)^2 = 33640/(8.022)^2 = 522.74 \text{ mm}^2$ .

tant stone factor in determining the modality of treatment and predicting clearance.

Stone bulk is correctly represented by stone volume. Volume of the stone can be measured by CT scan. Software is available with CT scan that accurately determines stone volume.<sup>5</sup> In most centers, estimating stone volume may be impractical in view of the cost involved and time taken for computerized reconstruction.<sup>4</sup> Determining volume is not necessary because stone area correlates well with stone volume.

The methods for determining stone surface area, such as graph paper, planimeter, and various computer systems, are cumbersome, not cost effective, or inaccurate.<sup>4</sup> The PICA 88 written in BASIC for an IBM-compatible personal computer that allows a sonic digitizer to estimate the area of a renal stone from a radiographic image was one of the first programs that enabled two-dimensional measurements of a stone image by computer.<sup>4</sup> Technology has developed since then to make image capturing and analysis user-friendly and commercially available at reasonable costs to be part of any urology office.

There are also other available image analyzers. The NIH Image Software is available from the National Institutes of Health.<sup>6</sup> In PACS (Picture Archiving and Communications System), all radiologic images can be analyzed in the work station. Surface area of stones may be measured depending on the software module available. So exporting the images to another computer is not necessary. But if PACS is not available, the technique outlined above is accurate, easy, and reproducible.

We used a digital camera for image acquisition, but in case a digital camera is not available, the stone image may be traced onto graph paper, which can then be scanned by a digital scanner. This image can then be opened in Adobe Photoshop. The area in pixels (A) of the traced stone image is then measured using the lasso tool and histogram box. One centimeter in the graph paper image can then be cali-

brated to "D" pixels. The area in  $\text{mm}^2$  is then calculated  $(A/(D/10)^2)$ .

To save time when multiple stone measurements are needed, as in a retrospective study, multiple stone tracings can be indexed and plotted onto a large graph paper, which can then be captured by a digital camera or scanner. The image of the graph paper with multiple tracings is then transferred to the image analyzer for rapid measurements of all stone images in a single capture.

The infundibulo-pelvic angle, height, length, width, etc., can also be assessed with a simple application of the Measure tool. Some authors have also tried to predict the chemical composition of the stone using the imaging program.<sup>7</sup>

## Conclusion

Measuring stone surface area using the imaging program reduces human error, especially when multiple and larger measurements are needed. It is accurate, fast, and highly reproducible.

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## Disclosure Statement

No competing financial interests exist.

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