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SUV navigator enables rapid [18F]-FDG PET/CT image interpretation compared with 2D ROI and 3D VOI evaluations

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Abstract

Purpose: Positron emission tomography (PET) and the maximum standardized uptake value (SUVmax) is a useful technique for assessing malignant tumors. Measurements of SUVmax in multiple lesions per patient frequently require many time-consuming procedures. To address this issue, we designed a novel interface named SUV Navigator (SUVnavi). The purpose of this study was to investigate the utility of SUVnavi.

Materials and methods: We measured SUVmax in 661 lesions from 100 patients with malignant tumors. Diagnoses and SUVmax measurements were made with SUVnavi, 2D, and 3D measurements. The accuracies of SUV measurements in each method were also evaluated.

Results: The average reduction in the time with SUVnavi versus 2D was 53.8%, and versus 3D was 37.5%; the time required with SUVnavi was significantly shorter than with 2D and 3D ($P < 0.001$ and $P < 0.001$). The time reduction and lesion number had a positive correlation ($P < 0.001$ and $P < 0.001$). SUVmax agreed with precise SUVmax in all lesions measured with SUVnavi and 3D, but in only 466 of 661 lesions (70.5%) measured with 2D.

Conclusion: SUVnavi may be useful for rapid F-18-FDG PET/CT image interpretation without reducing the accuracy of SUVmax measurement.

Key words:

FDG PET, image interpretation, Standardized Uptake Value, SUV measurement

I. Introduction

Positron emission tomography/X-ray computed tomography (PET/CT) performed with 2-[18F]fluoro-2-deoxyglucose (F-18 FDG) has become a useful and important oncologic technique[1-2]. F-18-FDG PET/CT is recommended not only for preoperative staging and evaluation of recurrence[3-6] but also for assessment of therapeutic responses[7-8]. The maximum standardized uptake value (SUVmax), a simple and semiquantitative index of tumor metabolic activity, is widely used in oncologic F-18-FDG PET/CT studies. Recent investigations have demonstrated that SUVmax is a significant prognostic factor for overall survival and distant metastasis/recurrence-free survival[9-20].

Moreover, two sets of criteria are available to quantify treatment responses in malignant tumors. The first set of criteria was developed by the European Organization for Research and Treatment of Cancer (EORTC) and published in 1999 by Young et al. [21]. The second set is the PET Response Criteria in Solid Tumors (PERCIST), which was published in 2009 by Wahl et al.[22]. An evaluation of SUV is necessary for both criteria.

Malignant lesions often extend in all directions. Therefore, it is sometimes difficult for nuclear medicine physicians and radiologists to identify the location of maximum uptake within a lesion, and SUVmax measurement therefore requires many procedures, a long time-, and great effort.

Some manufacturers have developed semi-automatic SUV estimation tools. A typical tool creates a volume of interest (VOI) using a certain SUV threshold of the uptake in the lesion, and measures SUVmax in VOI. However, these tools are ineffective for lesions with low SUV because the contrast between FDG uptake in abnormal lesions and normal

tissues is not high; therefore, an appropriate VOI creation is sometimes not achieved. In addition, the performance of these tools is insufficient for lesions proximal to other areas with another abnormal uptake or normal physiological uptake such as bladder[23-24] because discrimination between the uptake of the target lesions and other areas is difficult due to relatively low spatial resolution of PET image[25]; consequently, VOI size and threshold should be manually adjusted by experienced nuclear medicine physicians and radiologists in those cases.

To address these problems, we devised a novel interface named SUV Navigator (SUVnavi). This interface was designed for accurate, rapid, and easy measurement of SUVmax in a lesion.

We hypothesized that SUVnavi could accelerate the diagnostic process. The purpose of this study was to investigate the utility of SUVnavi for reducing the time required and for accurate measurement during image interpretation of SUVmax on F-18 FDG PET/CT. Furthermore, accuracy of SUVmax measurements was also evaluated.

II. Methods

A. Subjects

From 2012 to 2014, 100 patients (mean age, 64.6 ± 12.7 years; range, 24–87 years; 60 men and 40 women) suspected of having malignant tumors were included in this study. We measured SUVmax in a total of 661 lesions from those patients.

The protocol was approved by our institutional research ethics committee in accordance with the principles of the Declaration of Helsinki (approval number: 15160). The

informed consent was not deemed necessary by the ethics committees because this study was retrospective and noninvasive.

B. FDG PET scan

Each patient received an intravenous bolus of 185 MBq of F-18-FDG, and PET/CT images were acquired according to standard protocols using a PET/CT device (Discovery VCT, 64 multislice spiral CT; GE Healthcare, Milwaukee, USA). Acquisition began at 60 min after the injection of F-18-FDG. All patients fasted for 6 h before the injection.

A nonenhanced low-dose CT scan was acquired at 120 keV with auto-mA (20–100) for attenuation correction and anatomic localization, pitch of 0.98:1, rotation speed of 0.6 seconds, table speed of 39.37mm / rotation. Data were reconstructed with a standard filter into transaxial slices with a field-of-view of 50 cm, matrix size of 512 × 512 (pixel size, 0.98 mm), and slice thickness of 3.75 mm.

After the CT scan, PET images were obtained in three dimensions. The acquisition time per bed position was 3 min, and the scan had eight bed positions (head to mid-thigh). The scan field-of-view was 60 cm. The attenuation correction was based on the CT scan. The PET data were reconstructed into transaxial slices with a matrix size of 128 × 128 (pixel size, 4.69 mm) and a slice thickness of 3.3 mm using iterative 3D-OSEM (two iterations, 14 subsets) with a 5.14-mm gaussian postprocessing filter. The resulting PET and CT images were coregistered on hardware (Advantage Workstation version 4.4; GE Healthcare, Milwaukee, USA).

C. SUVnavi

We used Visual Studio 2010 (Microsoft Corporation, Redmond, WA, USA) to develop

PET/CT viewer software with SUVnavi. Our software is able to read DICOM files and display transaxial, sagittal, coronal, PET, CT, and PET/CT fusion images on a personal computer with a Windows 7 64-bit operating system (Microsoft Corporation, Redmond, WA, USA). The data were transferred via ethernet connection without delay. A comparison of current vs previous study is possible to load the multiple studies simultaneously. SUVnavi presents SUVmax information as bar graphs surrounding a cursor as well as actual values on several upper and lower slices simultaneously without paging (Figure 1). An operator can instantly identify the location of maximum uptake in the lesion because this information is updated in real-time. The algorithm is the following:

1. Get the X and Y positions of the cursor on the current slice.
2. A circle was drawn by the software. The center position of the circle is (X, Y). The radius is designated by the user.
3. Search the SUVmax inside of the circles.
4. Search the SUVmax inside of circles with designated radius on the current, several upper and lower slices. The center positions of the circles are (X, Y) on each slice. The number of slices is designated by the user.
5. Show SUVmax as graph bars on SUVnavi.
6. Move to the slice which has highest SUV among the obtained SUVmax.
7. A ROI is placed with visual confirmation without including adjacent high physiological uptake by the user.
8. The SUVmax in the lesion was obtained.

These procedures will be immediately performed when the position of cursor is changed. Diagnoses and SUVmax measurements were made in a randomized order by two nuclear medicine physicians using 3 methods, as follows: 1) our viewer software with SUVnavi,

2) slice by slice 2D SUV measurement on the manufacturer's viewer software (2D measurement, AW 4·4, GE), 3) volumetric 3D SUV measurement on the manufacturer's viewer software (3D measurement, AW 4·4, GE). Half of the subjects (N = 50) were evaluated first with SUVnavi and then 2D and 3D measurement. The remaining subjects (N = 50) were evaluated first 2D and 3D measurement, and then with SUVnavi. After performing these evaluations, precise SUVmax was measured under all the 3 methods to assess the accuracies of measured SUVmax. If the SUVmax were same in all methods, the SUVmax was considered as precise SUVmax. Otherwise, we repeated measurements of SUVmax in all method until all the SUVmax were equal, and then the obtained SUVmax was used as precise SUVmax.

D. Statistics

A t-test with Bonferroni correction was used to analyze differences in the time required to generate F-18-FDG PET/CT reports between 2D measurement (Time_2D), 3D measurement (Time_3D), and SUVnavi (Time_SUVnavi). The saved time by using SUVnavi compared with 2D and 3D measurement (s-Time_2D and s-Time_3D, respectively) were calculated using the following formula: s-Time_2D = (Time_2D) - (Time_SUVnavi); s-Time_3D = (Time_3D) - (Time_SUVnavi). The relationship between s-Time and lesion number was assessed using Pearson's correlation coefficient. A t-test was used to evaluate the differences between SUVmax with the 3 methods (2D measurement, 3D measurement, and SUVnavi) and precise SUVmax. A p value of less than 0.05 was considered significant. All the statistical analyses were performed with GraphPad Prism ver.6 (GraphPad Software, Inc., CA, USA).

III. Results

The average of SUV measured lesions in each scan was 6.6 lesions. The average Time_2D, Time_3D, and Time_SUVnavi were 11.1 min, 7.3 min, and 4.5 min, respectively; the average time reduction with SUVnavi versus 2D measurement was 53.8%, with a maximum reduction of 91.6%, and versus 3D measurement was 37.5%, with a maximum reduction of 71.1%. The Time_SUVnavi was significantly shorter than the Time_2D and Time_3D ($P < 0.001$ and $P < 0.001$; Figure 2). The s-Time_2D and s-Time_3D ranged from 0.02 to 32.0 min (average 6.6 min), and from 0.2 to 10.7 min (average 2.8 min), respectively. The s-Times_2D and s-Times_3D had a positive correlation with lesion number (Figure 3). Two hundred eighty seven of 661 lesions (43.4%) required the adjustment of VOI size or threshold with 3D measurement.

The measured and precise SUVmax agreed in only 466 of 661 lesions (70.5%) measured with 2D measurement, and all 661 lesions (100%) measured with 3D measurement and SUVnavi. In the lesions with discrepant SUVmax, those measured with 2D measurement were overestimated in 15 of 661 lesions (2.3%) and underestimated in 180 lesions (27.2%). The average SUVmax measured with 2D measurement was significantly smaller than precise SUVmax (Figure 4).

IV. Discussion

In this study, we demonstrated that compared with 2D and 3D measurements, the use of SUVnavi reduced the time of SUVmax measurement without reducing the accuracy.

The effect of reducing the time may have primarily originated from SUVnavi because s-Time and lesion number had a positive correlation. Approximately 43% of lesions actually required the adjustments of size or threshold with 3D measurements, and the procedures were probably time-consuming.

The perception of colors and shades by the human eye is limited; accordingly, the detection of the maximum uptake location is sometimes difficult. Therefore, the nuclear medicine physician and radiologist must frequently change the viewer window level and width and must identify the slice and location of the maximum lesion uptake to obtain precise SUVmax. This procedure requires huge amount of time and effort in 2D measurement. The procedure will be simplified by using 3D measurement, however, SUVmax location is occasionally placed in adjacent very high physiological uptake such as bladder to measure SUV of an intrapelvic tumor or metastatic lymph node with 3D measurement, consequently, frequently adjustment of VOI size or threshold may be required. SUVnavi can reduce both the required time and effort because it shows the three-dimensional SUVmax at a glance, move to the slice which has highest SUV among the obtained SUVmax, and the SUVmax of lesion is measured. The ROI is placed with visual confirmation without including adjacent high physiological uptake. In fact, our results showed that the time required to perform SUVmax measurement was reduced with SUVnavi. This effect was particularly remarkable for patients with many abnormal lesions.

SUVnavi may have several advantages over conventional interfaces. First, SUVnavi may accelerate PET/CT image interpretation without reducing the accuracy of SUVmax measurement. Expedited image interpretation will reduce patient and clinician waiting times. Some readers may think the power of SUVnavi is trivial. However, many

nuclear medicine physicians and radiologists have to generate a large number of reports, and we believe that SUVnavi will be necessary in busy institution. Actually, we managed approximately 1450 FDG-PET/CT scans per year before using SUVnavi, but we could recently perform up to 1800 scans per year with SUVnavi. Second, SUVnavi will reduce the fatigue of nuclear medicine physician because less time and effort will be required to generate a PET/CT report.

SUVnavi is useful for identifying the region of maximum uptake. In the present study, the interface was applied to evaluate SUVmax. In principle, SUVnavi can also be used to evaluate the SUV peak. Furthermore, SUVnavi may be useful for other indices, including tumor metabolic volume, because the SUVmax in the lesion is required to evaluate these other indices.

Several limitations of the present study should be noted. First, this was a retrospective study limited to a single institution. In principle, SUVnavi is useful for rapid, and easy measurement of SUVmax in any circumstance because its advantage does not depend on a PET/CT scanner, tracer, patient profile, or condition; however, multicenter randomized trials of SUVnavi are required to confirm its effects. Second, the order of software use may have affected the results. However, the order of use likely did not change the results because, as mentioned above, half of the subjects were first evaluated with SUVnavi, whereas the rest were evaluated first without SUVnavi.

V. Conclusion

In conclusion, SUVnavi may be useful for rapid and easy F-18-FDG PET/CT image interpretation without reducing the accuracy of SUVmax measurement.

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Figure legends

Figure 1

SUVnavi indicating SUVmax in several upper and lower slices simultaneously without paging. The SUVmax shown is the value from the lower slice (green bar) rather than the current slice.

Figure 2

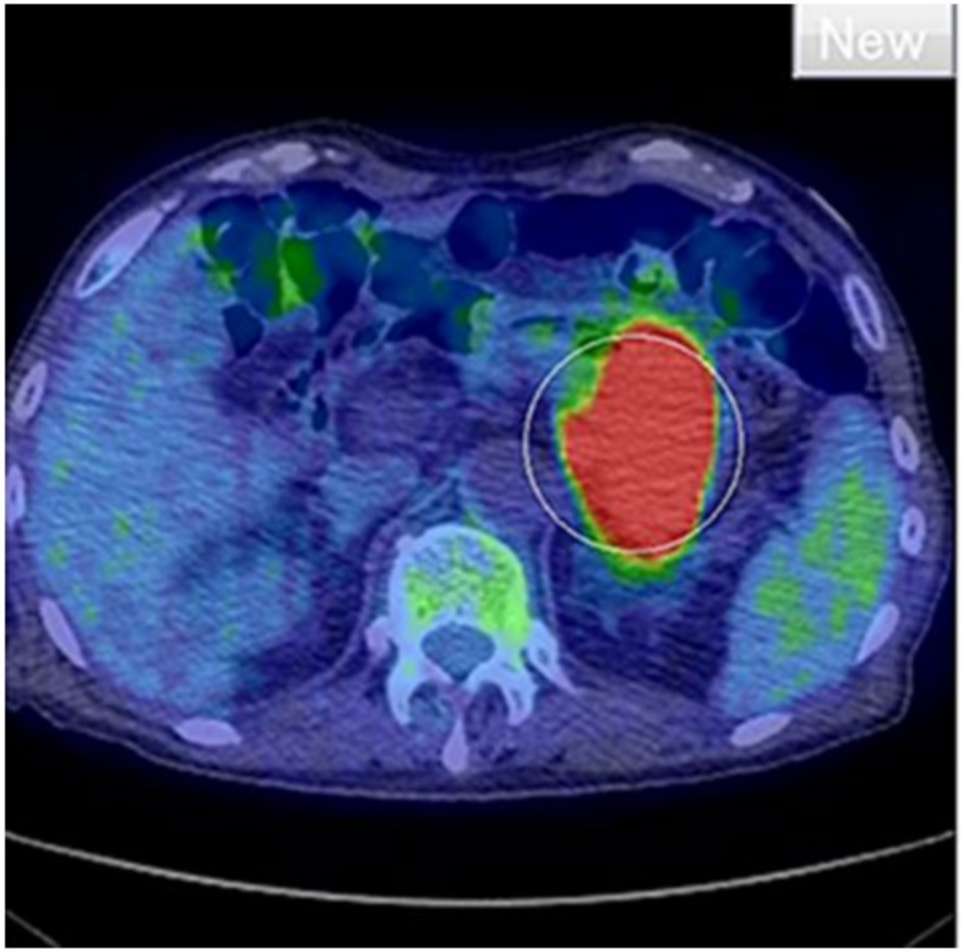
Bar graph showing the average Time_2D (dotted bar), Time_3D (hatched bar), and Time_SUVnavi (white bar). Each error bar represents the 95% confidence interval. Time_SUVnavi was significantly shorter than the Time_2D and Time_3D.

Figure 3

Scatter plot of s-Time_2D and lesion number (Figure 3A), and s-Time_3D and lesion number (Figure 3B). These variables were positively and statistically significantly correlated (Figure 3A: $y = 0.64x + 2.42$, $r = 0.56$, $P < 0.001$; Figure 3B: $y = 0.27x + 0.96$, $r = 0.62$, $P < 0.001$).

Figure 4

Bar graph showing average SUVmax measured with 2D measurement (dotted bar), 3D measurement (hached bar), SUVnavi (white bar), and precise SUVmax (black bar). Each error bar represents the 95% confidence interval. The average SUVmax measured with 2D measurement was significantly smaller than precise SUVmax (6.07 ± 0.25 vs. 6.31 ± 0.26, $P < 0.001$).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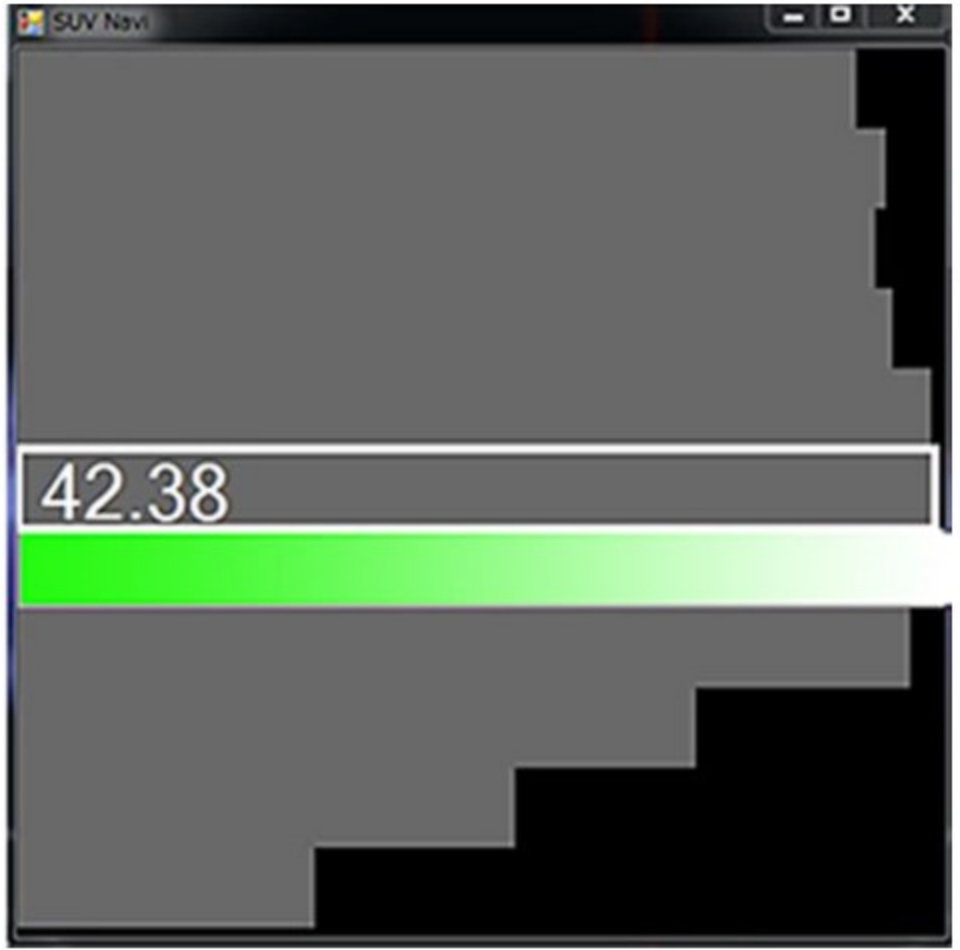
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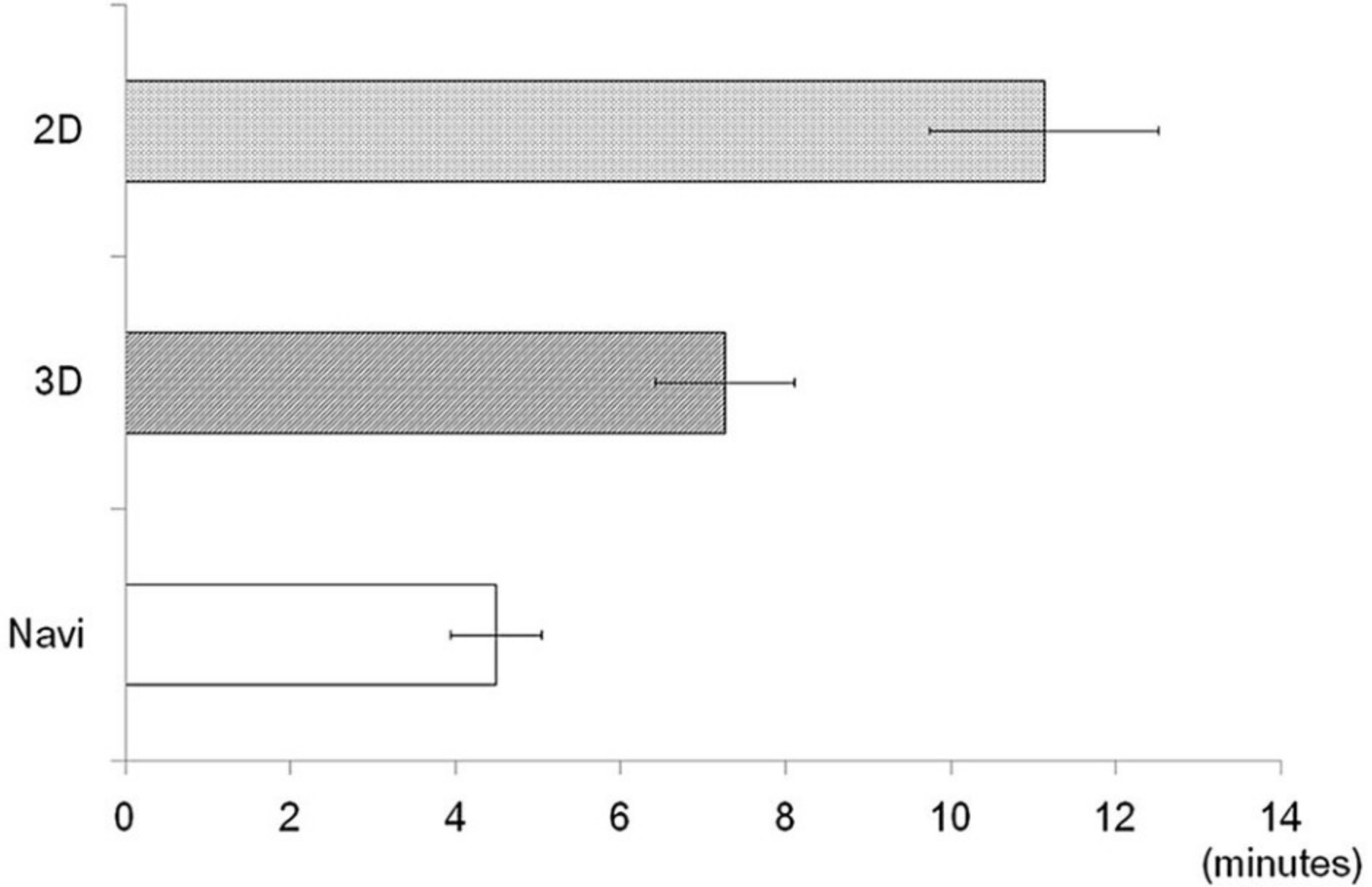
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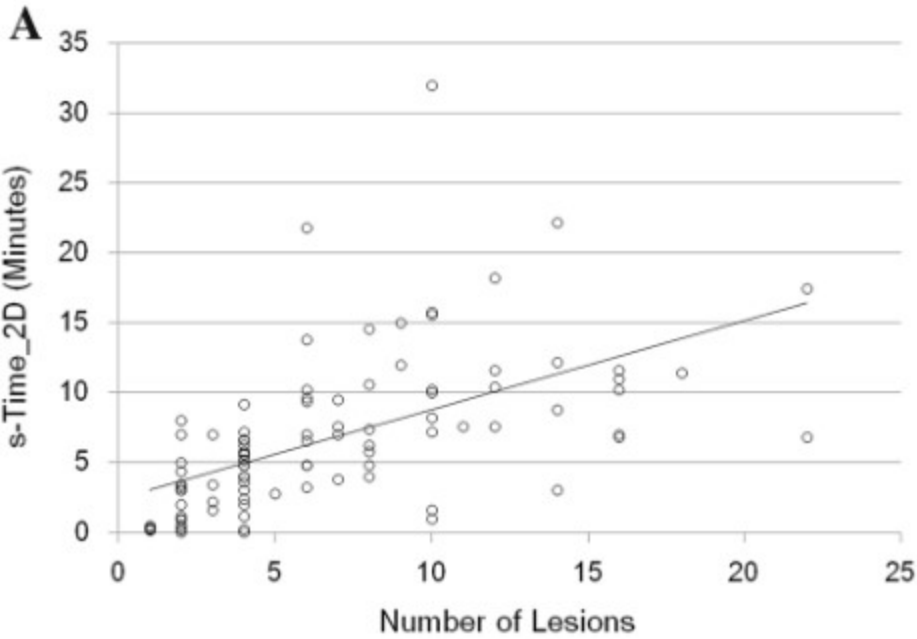
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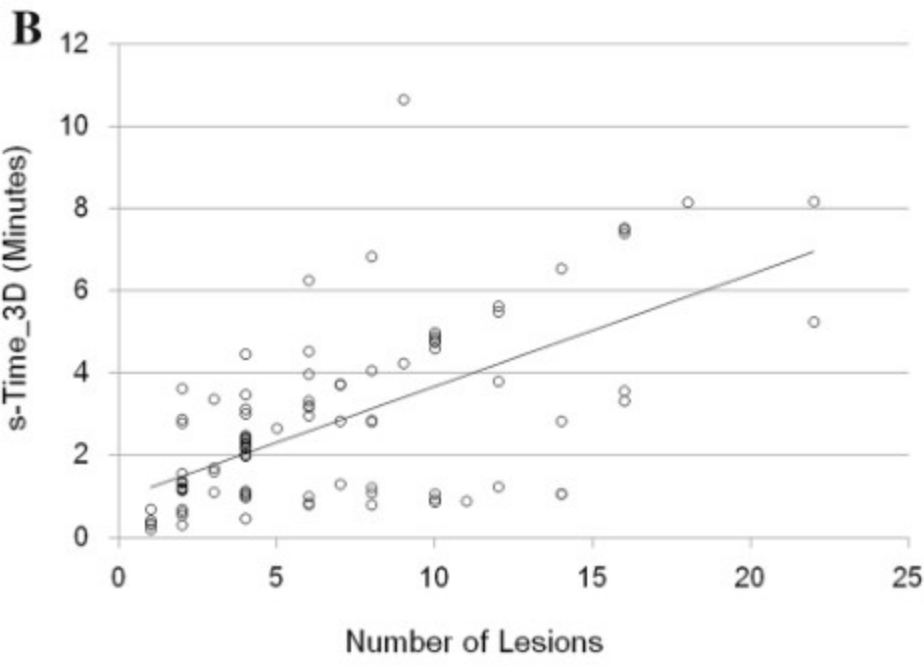
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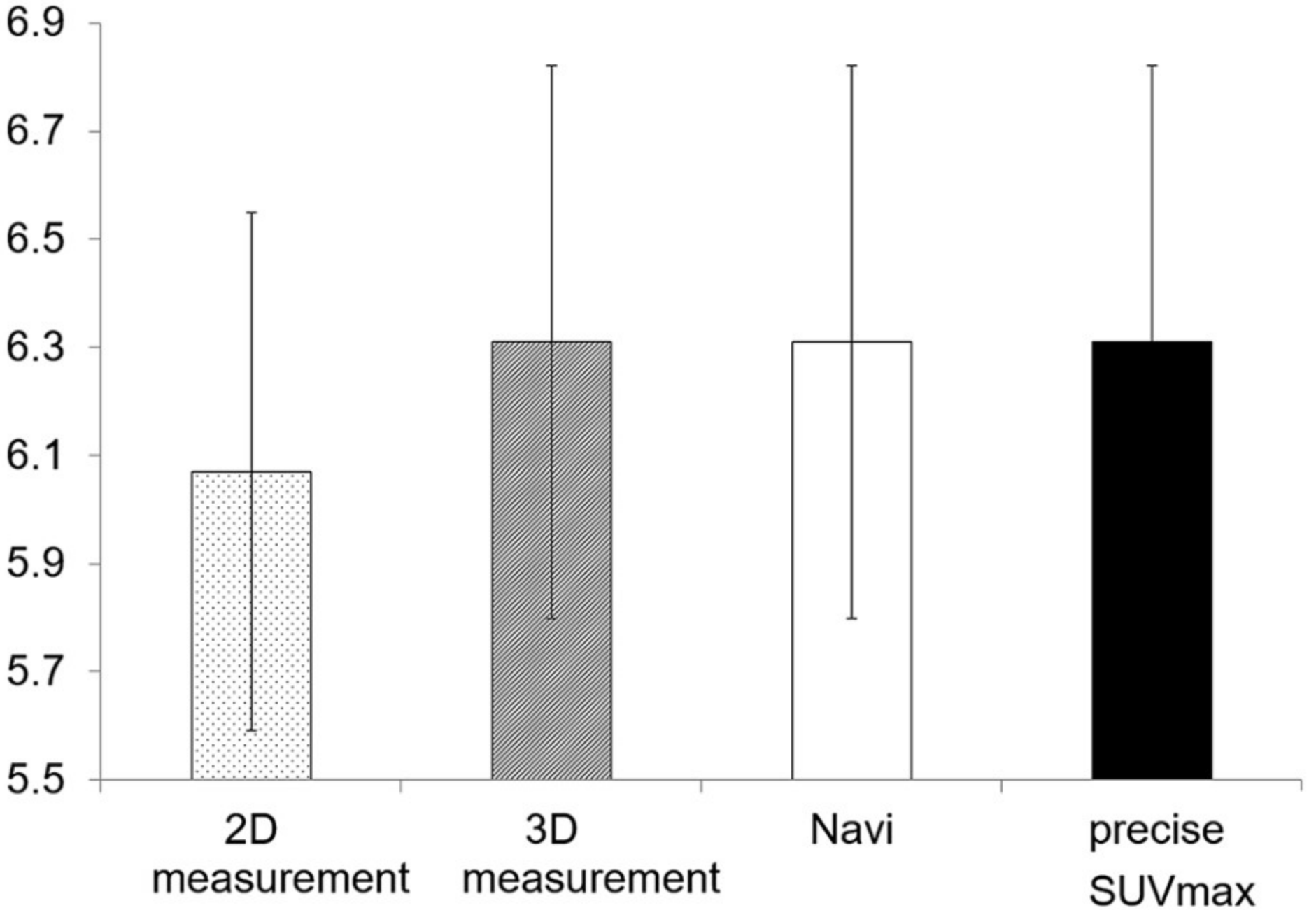
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