

The comparison of attenuation factor of ^{99m}Tc and ^{153}Sm radionuclides in planar image using Mediso InterView™ XP and ImageJ

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Abstract: Planar imaging quantification is a method in internal dosimetry studies that is needed in the preparation and post-therapy evaluation stages. The attenuation factors are needed in Conjugate View Method to obtain accurate image quantification results. In nuclear medicine installation, the high workload of integrated software slows the quantification process, so it is necessary to advance alternative software that is portable and has high accuracy. This study aims to compare the result of attenuation factors using InterView™ XP and ImageJ plug-in software. The study was conducted by observing attenuation of ^{99m}Tc and ^{153}Sm , which have 1, 2, 4, and 25 mCi activities on water slabs phantom with thickness variations of 1–10 cm using a Mediso Anyscan S equipped with Low-Energy High-Resolution collimator. Radionuclides activity measurement was performed using a dose calibrator. The energy window of each radionuclide is adjusted to the spectrum range in the gamma camera software. Image quantification was executed with InterView™ XP and ImageJ plug-in software. The attenuation factor is obtained by plotting a graph between count versus slab thickness. Analysis result using InterView™ XP and ImageJ software sequentially is $0.140 \pm 0.007 \text{ cm}^{-1}$, $0.140 \pm 0.009 \text{ cm}^{-1}$ (^{99m}Tc), and $0.128 \pm 0.004 \text{ cm}^{-1}$, $0.128 \pm 0.004 \text{ cm}^{-1}$ (^{153}Sm) at activity range 1–25 mCi. The result of Paired Samples t-test between ImageJ towards integrated InterView™ XP software shows that the value of Significance (2-tail) $> \alpha$; thus, H_0 is accepted. It is concluded that ImageJ software is quite accurate in determining the value of attenuation factors.

Keywords: factor, activity, radionuclide, internal dosimetry

1. Introduction

Based on WHO data in 2020, the total addition of cancer cases in the world has reached 19,292,789¹. Furthermore, cancer cases rise in Indonesia has reached 396.914². It is estimated that by 2040 there will be an increase of 33.22%². Nuclear medicine is one of modalities in health facility that plays an essential role in cancer management. Nuclear medicine procedures can provide a diagnosis for therapeutic decisions to achieve appropriate treatment³. In BAPETEN Chairman Regulation (BCR) No.17 in 2012, nuclear medicine is a specialist medical facility that utilizes open sources radionuclides for diagnostic (in-vivo or in-vitro), therapeutic, and clinical medical research based on physiological, pathophysiological, and metabolic processes⁴. The wide application in nuclear medicine has raised awareness of nuclear medicine's application for diagnostic and therapeutic procedures⁵.

The gamma camera is used to capture and project the distribution of gamma rays emitted by radionuclides that have been injected into the patient's body. The image that will be formed by the gamma camera is a two-dimensional (2D) or planar image of a three-dimensional (3D) spatial distribution emanating from radionuclides. Gamma camera usually consists of large scintillation crystals paired with hundred pieces of PMT (Photomultiplier Tube)⁶. This research is conducted using planar image in gamma camera. ^{99m}Tc is the most widely used radionuclides in nuclear medicine. Mainly 70% of its application is for diagnostic⁷. The diagnostic procedures using ^{99m}Tc have been done about ±30,000,000 per year globally⁸. ^{99m}Tc radionuclides are used in imaging for thyroid (^{99m}Tc-Pertechnetat), bone scan (^{99m}Tc-MDP, ^{99m}Tc-HDP), kidney study (^{99m}Tc-DTPA), cardiac study, breast or soft tissue (^{99m}Tc-MIBI), liver and gallbladder (^{99m}Tc-disofenin)^{4,9,10}. Another locally available radionuclide is ¹⁵³Sm. ¹⁵³Sm is used in palliative bone therapy in cancer or metastasis from another organ. ¹⁵³Sm is proven to relieve pain better than analgesic therapy that is usually used¹¹.

^{99m}Tc and ¹⁵³Sm are essential radioisotopes in nuclear medicine in diagnostic and therapy. The utilization of ^{99m}Tc and ¹⁵³Sm should be supported by the data for preparation in pre-therapy dosimetry study and post-therapy evaluation by performing an image quantification. Conjugate View Method is a well-known method in image quantification that can represent the distribution value before attenuating by the patient's body¹². Attenuation factor is needed to correct the cps value that has decreased due to attenuation¹³. Based on the Conjugate View Method equation, the intensity of photons detected (P_1 , P_2 , P_G) depends on the attenuation factor (μ), attenuator thickness (d), and radionuclides energies¹².

$$P_1 = I_0 e^{-\mu d_1} \quad (1)$$

$$P_2 = I_0 e^{-\mu d_2} \quad (2)$$

$$P_G = \sqrt{P_1 P_2} = I_0 e^{-\mu(d_1 + d_2)/2} \quad (3)$$

The high workload at nuclear medicine installation in performing diagnostic and therapeutic might cause difficulty in analyzing attenuation factors using integrated software (InterViewTM XP) on the operator's computer. Consequently, alternative software is required, which has high accuracy, is portable, and is easier to operate. The processing can be performed offline separately using other computers and softwares which can reduce the workload of operators on duty. In this research, ImageJ plug-in with the same function as integrated software is created to execute image quantification to get the cps value. The attenuation factor value was obtained by processing the cps value. The result of attenuation factor value using ImageJ plug-in and InterViewTM XP was compared by conducting a paired sample t-test.

2. Materials and methods

This study carried out radionuclides source preparation, image acquisition, software development, image quantification using integrated software InterViewTM XP (Mediso, Hungary), ImageJ (NIH, US), and statistical analyses with SPSS. Radionuclides preparation started with a dilution of Sodium Chloride (NaCl) and ^{99m}Tc or ¹⁵³Sm radionuclide with the small activity. Radionuclides with different activities were filled in a small syringe to get the point source image. The radionuclide activity was measured with Dose Calibrator Cometer IBC Lite.

A gamma camera Mediso Dual Head Anyscan S Series AS-105061-S was used with planar imaging protocol. The source activity range of radionuclides is 1, 2, 4, and 25 mCi in ^{99m}Tc and ¹⁵³Sm. The image acquired by the gamma camera is a two-dimensional (2D) image¹⁴. The accuracy of planar imaging is higher than SPECT in the imaging quantification process for determining radiation doses¹⁵. The set up of image acquisition process is presented in Figure 1. Radionuclide sources with gamma energy 140 keV (^{99m}Tc) and 103 keV (¹⁵³Sm) were applied for this experiment. Hence, a parallel Low Energy High Resolution (LEHR) collimator is utilized to maximize sensitivity and image resolution. Water slabs phantom with varying thicknesses of 1 – 10 cm functioned as attenuators, which has a human equivalent density and a more manageable setup process than water slabs phantom¹⁶.

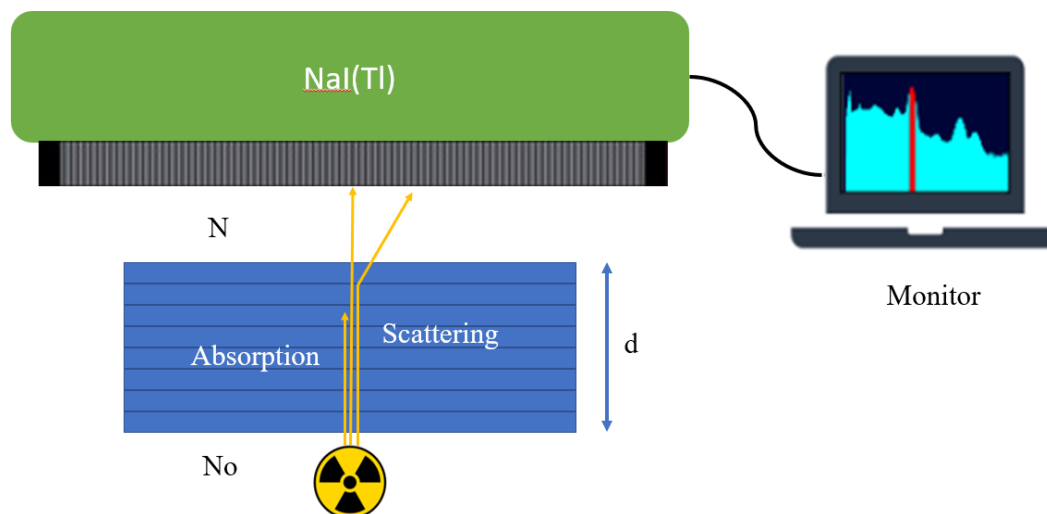


Figure 1. Image Acquisition Process

The reconstructed image was analyzed using InterView™ XP, integrated software from gamma camera Dual Head Anyscan S Series AS-105061-S by Mediso. InterView™ XP is capable of evaluating planar, whole body, and SPECT imaging. The count value of the image is taken by positioning the Rectangular Region of Interest (ROI) at the point source. The image quantification process is also executed with ImageJ software. This software is developed to read count in Rectangular ROI, equivalent to integrated software InterView™ XP. The count value in the ImageJ design was conducted by utilizing the RawIntDen function that could provide a total pixel value of intensity on an image with a predetermined ROI area¹⁷.

The average natural logarithm count per second (CPS) was calculated from the count value from the quantification result using integrated InterView™ XP and ImageJ Software divided by the acquisition time (60 seconds). Then a graph was plotted to show the relationship between the average result from the natural CPS logarithm and the thickness of the attenuator. The gradient of the graph is an attenuation factor in the quantification results of each software. The results of the attenuation factor obtained from the analysis using integrated InterView™ XP and ImageJ plug-in software were compared by conducting a paired sample t-test with $\alpha = 0.05$.

3. Result and discussion

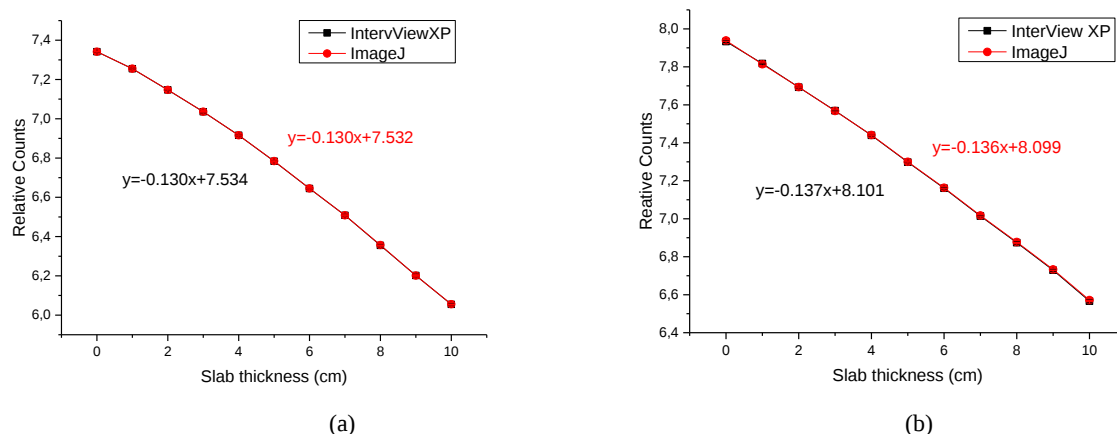
Images as acquisition results were quantified using InterView™ XP and ImageJ plug-in which are used to determine the count per second value for every image with varying attenuator thickness 1 – 10 cm from each activity. Based on the quantification process, the addition of the attenuator thickness decreases cps value will be gained. This statement is matched with the research conducted by Aranda-Lara, et al. (2014), Hossain, et al. (2015), and Hidayati et al. (2016), arguing that cps value is affected by attenuator thickness^{18–20}.

Descriptive statistical analysis was conducted to obtain attenuation factor values from every radionuclide activity²¹. Based on the RADAR Guide: Standard Methods for Calculating Radiation Doses for Radiopharmaceuticals, the attenuation factor value can be obtained by plotting a graph of the relationship between the cps natural logarithm value and the thickness of the attenuator. The value of the gradient formed on the graph is the value of the attenuation factor²². Reviewing Figure 2, the range of cps values in the acquisition of ¹⁵³Sm radionuclide images with an activity of 1,7 mCi at a slab thickness of 1 – 10 cm is 6.05 – 7.34 s⁻¹. While the range 6,4 – 8,0 s⁻¹ of the ^{99m}Tc with activity of 1,07 mCi. Table 1 presents the attenuation factor value (μ) of ^{99m}Tc dan ¹⁵³Sm radionuclides utilized from InterView™ XP and ImageJ.

Table 1. Comparison of Attenuation Factor in InterView™ XP and ImageJ Software

Source	Activity (mCi)	InterView™ XP			ImageJ		
		μ (cm ⁻¹)	Average μ	deviation	μ (cm ⁻¹)	Average μ	deviation
^{99m} Tc	1	-0,136	-0,140	0,007	-0,136	-0,140	0,009
	2,5	-0,150			-0,153		
	3,8	-0,133			-0,133		
	22	-0,139			-0,138		
¹⁵³ Sm	1,7	-0,130	-0,128	0,004	-0,130	-0,128	0,004
	3,24	-0,130			-0,130		
	4	-0,129			-0,129		
	25	-0,122			-0,122		

In the activity ranging between 1 – 25 mCi, attenuation factor value of ^{99m}Tc in quantification using integrated InterView™ XP and ImageJ plug-in software are 0.140 ± 0.007 cm⁻¹ and 0.140 ± 0.009 cm⁻¹, respectively. Then, the attenuation factor value of ¹⁵³Sm in quantification using integrated InterView™ XP and ImageJ plug-in software sequentially, 0.128 ± 0.004 cm⁻¹ dan 0.128 ± 0.004 cm⁻¹. The value of the attenuation factor is inversely proportional to the source energy. However, a ^{99m}Tc radionuclide with an energy of 140 keV has a higher attenuation value than ¹⁵³Sm with an energy of 103 keV. It occurred due to the higher sensitivity of the NaI(Tl) detector to ^{99m}Tc radionuclides than ¹⁵³Sm. The ^{99m}Tc radionuclide has a sensitivity of 31.21 cps/MBq, while the ¹⁵³Sm is 10.16 cps/MBq²³.

**Figure 2.** Attenuation factor (a) ¹⁵³Sm 1,7 mCi and (b) ^{99m}Tc 1,07 mCi**Table 2.** Normality Test Shapiro-Wilk

	Statistic	df	Significance
InterView™ XP	0,946	8	0,675
ImageJ	0,883	8	0,199

Table 3. Paired Sample t-test

	Mean	Std. Dev	Std. Error Mean	t	df	Significance (two- sided)
InterView™ XP – ImageJ	-0,001	0,002	0,006	-0,228	7	0,826

Accuracy of ImageJ plug in towards integrated InterView™ XP software was assessed by conducting paired sample t-test. Paired samples t-test was executed because the data obtained are normally distributed, as evidenced by the results of the Shapiro-Wilk normality test in Table 2, where the significance value of data is more significant than α ($0,200 > 0,05$). The initial hypothesis (H_0) in this test is that there is no significant difference between the attenuation factor processed using integrated InterView™ XP and ImageJ plug-in software if the value of significance (2-tail) is more than 0,05. The value of significance (2-tail) obtained in paired sample t-test shown in Table 3 is 0,826 (significance (2-tail) $> \alpha$). Thus, the valid conclusion in this statistical test is that the hypothesis (H_0) is accepted, or there is no significant difference between the value of the attenuation factor processed in integrated InterView™ XP and ImageJ plug-in software.

4. Conclusion

ImageJ plug-in software can be used as an alternative software that is accurate, portable, and easy to perform image quantification. It can be a solution to reduce integrated InterView™ XP software workloads. Based on the paired sample t-test on the attenuation factor value obtained from the quantification process of integrated InterView™ XP and ImageJ plug-in software, it can be concluded that there is no significant difference in the results of image quantification using the two softwares.

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