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A COMPARISON OF IMAGE QUALITY OF CERIUM OXIDE NANOPARTICLES AND IODINE CONTRAST AGENTS IN COMPUTED TOMOGRAPHY SCAN

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Abstract: Computed tomography (CT) scan, with iodine-based contrast, produces good image quality by improving the visualization of relatively low-contrast internal body structures. However, the impact of using iodinated difference should be considered in patients susceptible to contrast allergy and renal impairment. Therefore, alternative contrast materials, such as cerium oxide nanoparticles (CeO_2 NPs), must be used, with biocompatible properties and strong X-ray attenuation capabilities. This study compared the CT scan image quality of CeO_2 NPs and iodinated contrast agents. This experimental study started by preparing a suspension of CeO_2 NPs and iodine in double distilled water at a concentration of 500 ppm. The suspension was scanned using a CT scan with a helical scanning method. The exposure coefficient parameters were set for the tube voltage of 80 kV, Field of View of 28 cm, slice thickness of 5 mm, and tube current time of 150 mAs, 200 mAs, and 250 mAs. Then, CT images in DICOM data format were processed using MicroDICOM Viewer software. The quality of the CT scan images was analyzed based on the CT number value, noise level, and contrast resolution. The images of CeO_2 nanoparticles have higher CT values, lower noise levels, and better contrast resolution than those of iodine contrast agents. The results show that the CT image results of CeO_2 NPs have better quality than those of iodine-containing contrast agents

Keywords: *Nanoparticle CeO_2, Iodine Contrast Agent, Image Quality*

INTRODUCTION

Computed tomography (CT) scan is a diagnostic imaging modality with relatively fast image acquisition time and is relatively commonly used in the medical field [1-2]. With its different image projections, CT images can visualise the details of human anatomy and diagnose any organ abnormality. Therefore, a good-quality CT image is needed to assist physicians in performing medical diagnostic [3-4]. Commonly, CT image quality is improved by using iodine-based contrast agents. It is known that contrast agents have the potential to enhance the visualisation of structures within the body that have relatively small contrast targets, such as soft tissues and blood vessels [5]. However, contraindications that affect the usage of iodine-based contrast agents should be considered, especially for patients with a history of allergy to contrast agents and kidney problems [5-9].

The exposure factor setting during scanning also affects the quality of the CT image [10]. Providing a high exposure factor will result in better image quality. However, a higher exposure factor will result in higher patient radiation doses [11-12]. Therefore, it is necessary to optimise the exposure parameters, such as the duration of the CT current, to reduce the radiation dose the patient receives. In medical practice, balancing the patient's absorbed dose with the optimal acquired image quality is necessary for optimum diagnosis [13].

This study investigated the cerium oxide nanoparticles (CeO_2 NPs) suspension as an alternative contrast agent in the CT scan modality. CeO_2 NPs are biocompatible, have strong X-ray attenuation, and are widely used in the biomedical field [14-17]. The image quality of CeO_2 NPs was compared to the CT image quality of iodine contrast agents based on CT numbers, noise amount, and contrast resolution.

RESEARCH METHODS

The materials used in this study were CeO_2 NPs and an-iodine-based contrast agents. CeO_2 NPs were synthesised at a Laboratory of Material Physics, Universitas Diponegoro [18]. Iodine-based contrast was obtained from the commercial market. The research procedure starts by preparing a suspension of CeO_2 NPs and iodine at the same concentration in double distilled water (500 ppm). Next, the suspension was put into a 10 ml vial, as shown in figure 1. (a). Scanning of the sample images was performed using a GE Revolution EVO 128-slice CT scanning modality at the radiology installation of Indriati Hospital, Sukoharjo, Central Java. The exposure factor parameters are shown in Table 1. and the sample positioning during CT scanning is shown in Figure 1. (b).

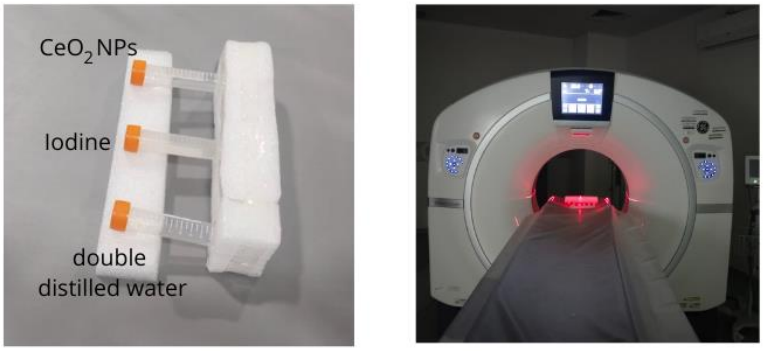
Table 1. CT *scan* Exposure factors

Exposure factors	Value
Tube Voltage (kV)	80
Time Current Tube (mAs)	150
	200
	250
Slice Thickness (mm)	5
Scan mode	Helical
Field of View (FOV)	28 cm

The obtained image scans were analyzed using sample images in DICOM data format. DICOM Viewer software created the region of interest (ROI) with a circular shape in the centre of the sample image. The ROI generated is one-quarter of the image area of the sample object or 25 mm^2. The ROI measurements yield the mean pixel intensity, representing the CT number, and the pixel standard deviation, representing the noise. The processed data is then calculated using Equation (1) to determine the contrast-to-noise ratio (CNR) value [5,8,19].

$$\mathrm{CNR} = \frac{\mathrm{I_{post}} - \mathrm{I_{pre}}}{\sigma} \quad (1)$$

Where I_{post} is the average intensity of the sample pixels, I_{pre} is the moderate intensity of the solvent pixels, and σ is the standard deviation of the sample pixel intensity.



(a) (b)

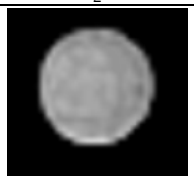
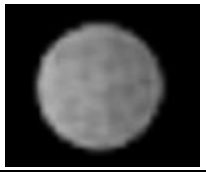
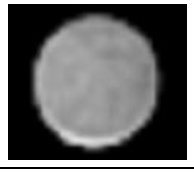
Figure 1. (a) Vial tube containing samples of double distilled water, iodine, and CeO_2 NPs (b) The sample positioning during CT scanning

RESULTS AND DISCUSSION

Analysis of CT Number

The CT images of CeO_2 NPs and iodine contrast agents for various current tube exposures are shown in Table 2. The color of the resulting image represents the object's ability to attenuate X-rays, and the black color is the low attenuation region [20], [21]. Based on the imaging data in Table 2, it can be seen that CeO_2 NPs and iodine contrast agents produce an image that appears whiter than double distilled water. Increasing the time current tube causes the image of both materials to be darker. Increasing the recent tube duration slightly decreased the CT number values for both materials. As shown in Figure 2, the CeO_2 NPs images have higher CT number values than iodine contrast agents for various time current tubes. The most significant difference in CT number values (3.7 HU) between CeO_2 NPs and iodine contrast agent images was achieved when the time existing tube was applied at 250 mAs. These results confirm that the CeO_2 NPs material has a more vital X-ray attenuation ability than iodine, resulting in whiter images.

Table 2. The CT images of CeO_2 NPs, Iodine and double distilled water

Time Current Tube (mAs)	Materials		
	double distilled water	Agen contrast Iodine	CeO_2 NPs
150			
200			
250			

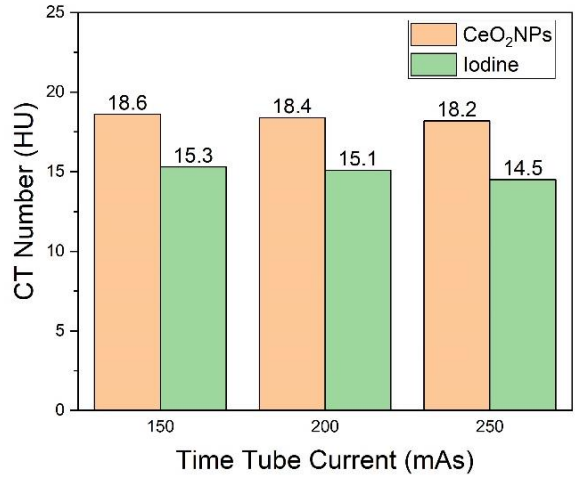


Figure 2. CT number diagram for CeO_2 NPs and iodine

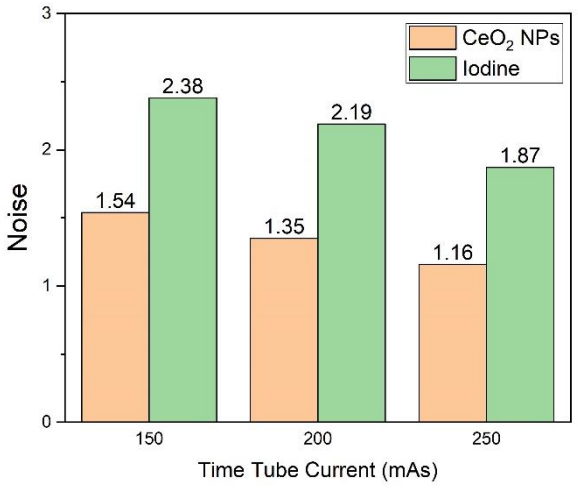


Figure 3. Noise image number diagram for CeO_2 NPs and iodine

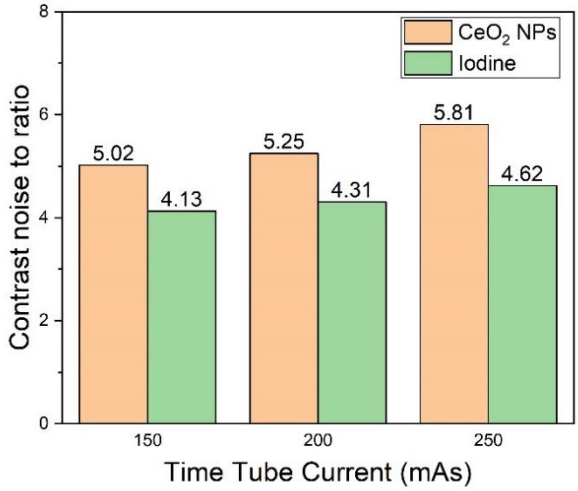


Figure 4. CNR Number diagram for CeO_2 NPs and iodine

Analysis of Noise Image

The ROI analysis on each CT image resulted in the standard deviation of pixel intensity representing the amount of noise in the image. Good-quality images have low noise. Based on the imaging data in Table 2, it can be seen that the CT image of CeO_2 NPs and iodine contrast agents appear whiter and more uniform than double distilled water. Increasing the time current tube makes the image of both objects appear smoother with more uniform whites. In general, increasing the time current tube further reduces the amount of interference in both materials. This result is to the research report by Bernstein et.al (2016) [22]. As shown in Figure 3, it can be seen that the CeO_2 NPs image has lower noise than the image of the iodine contrast agent for various time-current tubes. The most prominent noise difference between the CeO_2 NPs and iodine contrast agent images was 0.84 when the applied time tube currents of 150 mAs and 200 mAs were applied. These results confirm that the CeO_2 NPs material produces smoother images than iodine agent contrast. It is known that increasing the time current tube will create an increasing number of photons. Therefore, the intensity of photons reaching the detector also increases [1,23].

Analysis of image contrast resolution

Contrast resolution of an image is the ability to distinguish different objects and is greatly affected by the amount of image noise [10, 24]. Images with a good contrast resolution can be created with minimum noise. The contrast resolution of an image can be quantitatively analyzed based on the contrast-noise ratio (CNR) value [25]. Figure 4 shows the effect of the time current tube on the CNR value of both materials. It is known that the amount of image noise is inversely proportional to the CNR value. As shown in Figure 4, the CeO_2 NPs image has a higher CNR value than the iodine contrast agent for various time-current tubes. The most significant difference in CNR values between CeO_2 NPs and iodine contrast agent images was 1.19 for the time tube current of 250 mAs. These results reveal that CeO_2 NPs materials have higher image contrast resolution than iodine contrast agents. So, the objects with relatively low contrast can be distinguished.

This study shows that CeO_2 NPs have better CT image quality than iodine. CeO_2 NPs can produce whiter images with lower amounts of noise than iodine. The CNR value of CeO_2 NPs images was also higher than that of iodine. Increasing the time current tube of exposure factor setting will produce better quality images. However, the radiation dose received will also be more prominent. Imaging CeO_2 NPs with a low exposure factor can make good quality images with less than two noise. These results can be used as initial data to consider enhancing the potential of CeO_2 NPs as an alternative material for CT scans for contrast agents.

CONCLUSION

Based on the results of this study, it can be concluded that CeO_2 NPs have better CT scan image quality than iodine contrast agents. Increasing the time current tube generally leads to a decrease in the CT number value, a reduction in noise, and better contrast resolution in the images of CeO_2 NPs and iodine contrast agents.

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