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Original Research

The effectiveness of trivariate shrinkage computer radiography (CR) technique on image quality and anatomical information in radiotherapy geometric verification

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Abstract
Geometric verification is mandatory before radiotherapy treatment by comparing the image suitability results from the Computer Radiography (CR) imaging portal with the planned reference image at the TPS (Treatment Planning System). EPID is an advanced technology that has yet to be applied to all radiotherapy departments in Indonesia because it is commercial, so CR is an alternative to geometric verification. The purpose of analyzing the effectiveness of using the Denoising Technique with Trivariate Shrinkage CR compared to EPID in improving image quality and anatomical information on geometric radiotherapy verification. The research method quasy an experimental or pseudo-experiment with a pretest and posttest of one group with a control design. The respondents were all patients who underwent CR and EPID examinations. Determination of respondents using consecutive sampling so that the number of samples is obtained as many as 16. Denoising was performed using the Matlab Program with Trivariate Shrinkage on CR and compared with EPID. There are differences in anatomical information on geometric verification of radiotherapy performed before and after denoising using Trivariate Shrinkage, as seen from all variables obtained p-value <0.05. There was no difference in anatomical information on geometric verification of radiotherapy denoising using Trivariate Shrinkage on CR compared to EPID, as seen from the variable obtained p-value >0.05. In conclusion, the Trivariate Shrinkage Computer Radiography (CR) technique is effective in image quality and anatomical information in the geometric verification of radiotherapy. The Trivariate Shrinkage Computer Radiography (CR) technique can produce optimal images and provide good anatomical information comparable to EPID.

Keywords: trivariate shrinkage; image quality; anatomical information; computer radiography (CR); EPID

1. Introduction

Radiotherapy is a method of treating malignancy (cancer) by stopping and killing the growth of cancer cells. Radiotherapy utilizes ionizing radiation. Cancer management can be done using radiotherapy. Radiotherapy can be combined with chemotherapy (chemoradiation) or radiotherapy surgery (postoperative or intra/perioperative). Radiotherapy has external benefits, namely in cervical cancer (LC 33%, OS 18%) and head-neck cancer (LC 32%, OS 16%). External radiation (teletherapy) radiotherapy is proven to improve Local Control (LC) and overall survival (OS), especially in stage 2 cancer cases for five years. External radiation is a method of irradiation of radiotherapy with the radiation source located at a certain distance from the patient's body. The external radiation method provides a wide range of radiation in addition to the primary tumor in regional lymph nodes (Page et al., 2014; Dyer et al., 2019). Linear Accelerator (LINAC) has better benefits than Cobalt-60 because the potential source risk of Cobalt-60 itself is dangerous (Page et al., 2014). LINAC is a device used to accelerate particles or atoms that experience cross-straight acceleration due to differences between cathodes between the paths. Accelerators contain magnetic and electric forces to control particles' direction of motion. LINAC emits energy as Megavolts (MV) (Page et al., 2014). External radiation in radiotherapy planning to accurately determine the direction of light, selective type of light, and energy must be considered to prevent the occurrence of Organs at Risk (OAR). Homegenic radiation doses can be obtained on tumor masses. According to International Commission on Radiation Units (ICRU)

Reports 50 (1993), 62 (1999), and 83 (2007). Radiotherapy techniques, in general, are 2 Dimensional Technique (2D), 3 Dimensional Conformal Radiotherapy (3DCRT), Intensity Modulated Radiotherapy (IMRT) with a form of congruent use of Groos Tumor Volume (GTV), Clinical Target Volume (CTV), Planning Target Volume (PTV) from tumors (Zukauskaite et al., 2018).

The success of irradiation depends on verifying the irradiation setup (geometric). The purpose of verification of this irradiation setup is to ensure that the accuracy of the irradiation set-up given is within normal limits or is still obtained in irradiation planning. Geometric verification ensures the position and volume of a given irradiated tumor within planned limits. Verification can use Film, Computer Radiography (CR), and Electronic Portal Imaging Device (EPID) (Whittington, 2002).

EPID is a tool to measure the intensity of X-rays in advanced technology by transmitting through the patient during radiotherapy. The results of the radiation beam are converted into a 2D (2-dimensional) digital radiography image aimed at correcting the planned beam with the patient's anatomy. EPID is an additional tool (Hardware) that can be integrated with the LINAC aircraft in the digitization system that can be seen on a computer monitor. The main problem with LINAC is the low quality of the image produced in the use of MV energy released by LINAC and the occurrence of the Compton effect, thus requiring Digital Image Processing (DIP) to improve image quality alternatively (Dragun et al., 2013). EPID is an advanced technology that has yet to be applied to all radiotherapy departments in Indonesia because it is commercial, so CR is an alternative to geometric verification. DIP is processing image rays that are transformed into other image outputs using certain techniques (Shukla, 2017). One of the techniques to improve the image is image enhancement and restoration. The image enhancement technique uses an image, while this function distinguishes image restoration because it is carried out when obtaining sources of image degradation, such as point degradation (noise) or spatial degradation (blurring) (Vyas et al., 2018). The application of DIP can generally be done using Matlab software. Matlab is a simple coding software. All Matlab data variables are considered matrices, and processing matrices are for analyzing data. Matlab has different functions in toolbox applications, while DIP in Matlab itself has been widely used in technological advances, especially in medicine (Sinecen, 2016).

According to the results of research by Hakim et al. (2015) using DIP on EPID images in the Contrast Limited Adaptive Histogram Equalisation (CLAHE) software as an effort to denoising and improve the quality of radiotherapy images (Hakim et al., 2015). Based on a survey conducted at the Indonesian Radiotherapy Department, it is known that there still needs to be additional hardware software on EPID. Therefore, an alternative is needed that can be done by using CR for the imaging process. Research conducted by Robert et al. (2006) comparing the visibility of landmark anatomical information images (head and neck chest) between CR and EPID devices, in the results of images from CR, have results comparable to EPID (Roberts N & Stanley S, 2016). The high energy produced by LINAC can reduce image quality. Metal filter methods and combinations of material and thickness are carried out, with efforts to obtain good image quality. The shortcomings of this study are the results of object verification and different combinations of filter materials in each organ (Ryangga, 2011).

The application of Trivariate Shrinkage in CR is used for geometric verification, which aims to analyze the effectiveness of using denoising techniques with Trivariate Shrinkage CR compared to EPID in improving image quality and anatomical information on geometric verification of radiotherapy. Researchers assessed the improvement of image quality, which includes geometric verification (head and neck, chest), comparing the resulting anatomical image information (before and after), and accommodating the needs of radiation oncologists, medical physicists, and radiation therapists with image quality in optimal anatomical information in conducting geometric verification. Based on the background above, the researcher wants to do further with the title "The Effectiveness of the Trivariate Shrinkage Computer Radiography (CR) Technique on Image Quality and Anatomical Information on Geometric Radiotherapy Verification" to analyze the effectiveness of using the Denoising Technique with Trivariate Shrinkage CR was compared to EPID in improving image quality and anatomical information on geometric verification of radiotherapy.

2. Research Methods

2.1.Research Design

The type of research used in this study is quasy experimental research or experiments, all with pretest and posttest one group design with control design used to prove the effect of trivariate shrinkage denoising technique on geometric verification to the quality of imagery and anatomical information. This research was conducted on humans to obtain objective results. The study used posterior and lateral anterior techniques using photon energy and image capture adjusted to hospital SOPs. The objects carried out geometric verification are the head, neck, and chest. The image results obtained in digital form are then processed using the Matlab program and compared with EPID.

2.2.Samples and Sampling Techniques

The population in this study was all patients who underwent CR and EPID examinations at Ken Saras Hospital Semarang in January 2022. Determination of the number of samples using the non-probability sampling method with consecutive sampling and based on inclusion and exclusion criteria with the number of respondents as many as 16 images.

2.3.Instruments

The research instruments used in this study are LINAC aircraft, CR image plate, Bukystand, Matlab Software, approval sheets to become observers, laptops, and checklists. Making denoising software with the Trivariate Shrinkage technique. Software development is done with the help of experts in Matlab. The imaging plate is processed using CR, and the results will be analyzed using the Matlab program with Trivariate Shrinkage.

2.4.Intervention

This research has a mechanism or stage in research, and the first is that researchers take care of licensing to the ethics commission of the Semarang Ministry of Health Poltekkes, Semarang City Health Office, and Semarang Ken Saras Hospital. In the second stage, researchers collect data starting from preparation with the preparation of proposals, preparation of research instruments, and management in ethics or ethical clearance. Then, the implementation of this research began with the creation of Software Denoising with the Trivariate Shrinkage technique. Software development is done with the help of experts in Matlab. Researchers conduct CR and EPID examinations on respondents by predetermined SOPs, from preparation to position arrangement by TPS (Treatment Planning Systems) planning. Respondents were positioned supine (sleeping on their backs) on the LINAC examination table in a head-first position. Graticule S2N18 is mounted on a LINAC collimator gantry.

The imaging plate is processed using CR, and the results will be analyzed using the Matlab program with Trivariate Shrinkage. After denoising using the Matlab program with Trivariate Shrinkage, the data is analyzed visually, subjectively, and objectively. After denoising Trivariate Shrinkage, it was compared with EPID and subjective visual analysis was carried out. Subjective and objective visual analysis. Evaluate subjectively by visually assessing the observer, namely oncological radiation. This assessment is carried out by providing questionnaire sheets to observers to assess the results of image quality improvements that have been made. The value given is 1,2,3,4,5 for each image result.

2.5.Data Analysis

All data that has been collected is then processed and presented in a table of research data collection results. The collected data were analyzed with the SPSS program and then carried out non-parametric analysis tests (Wilcoxon and Mann Whitney tests). The data that has been prepared can be used as a basis for discussing the problem, which can then be tabulated and conclusions drawn.

2.6.Ethical considerations

In ethical considerations, researchers must first take care of and obtain permits for research that has been carried out from the Semarang Ministry of Health Poltekkes Postgraduate and carry out feasibility tests (ethical clearance) from the Health Research Ethics Commission (KEPK) Poltekkes

Kemenkes Semarang and Dr. Moewardi Surakarta Hospital with number 1,160 / XII / HREC / 2021, then conduct data collection and collection research. Data collection carried out by researchers certainly pays attention to ethical aspects, including anonymity, confidentially, and autonomy. Researchers ask respondents for informed consent before the study is conducted.

3. Results and Discussion

3.1. Research Results

Table 1. Characteristics of research samples based on age and sex based on demographic data

Category	Classification	Percentage (%)
Usia	40-45 years old	25
	46-50 years old	18.75
	51-55 years old	31.25
	56-60 years old	25
	Total	**100**
Jenis Kelamin	Man	56.25
	Woman	43.75
	Total	**100**

*Levene statistical homogeneity test
Source: Primary Data, 2021

Based on table 1 shows that in this study, the image samples used were aged 40 to 60 years, with the most widely used image samples being patient image samples ranging from 51-55 years. Regarding the gender of this study, the most widely used image sample was an image sample of male patients.

Table 2. Differences in the image of head and neck anatomical information before and after denoising with the Trivariate Shrinkage technique

Variable		*Mean*	SD	Delta	Z count	*p-value**	Information
Frontal Sinus	Pre-test	1.636	0.650	2.795	-5.882	0.000	There's a Difference
	Post-test	4.432	0.501				
Occiput	Pre-test	2.000	0.610	2.523	-5.843	0.000	There's a Difference
	Post-test	4.523	0.505				
Pituitary Fossa	Pre-test	1.591	0.542	2.864	-5.915	0.000	There's a Difference
	Post-test	4.455	0.504				
Orbital Ridge	Pre-test	1.750	0.866	2.636	-5.856	0.000	There's a Difference
	Post-test	4.386	0.493				
Maxila	Pre-test	1.727	0.727	2.841	-5.860	0.000	There's a Difference
	Post-test	4.568	0.501				
Cervical	Pre-test	1.682	0.601	2.773	-5.929	0.000	There's a Difference
	Post-test	4.455	0.504				

*Wilcoxon test
Source: Primary Data, 2021

Based on Table 2, it can be seen that the Wilcoxon test results for all variables obtained a p-value of <0.05. The Trivariate Shrinkage CR technique showed a significant difference in head and neck anatomical information in geometric radiotherapy verification before and after denoising.

Table 3. Differences in the image of chest anatomy information before and after denoising the Trivariate Shrinkage technique

Variabel		*Mean*	SD	Delta	Z count	*p-value**	Information
Lung Apex	Pre-test	2.000	0.725	2.650	-3.953	0.000	There's a Difference
	Post-test	4.650	0.489				
Sinus Gostophrenicus	Pre-test	1.950	0.826	2.650	-3.953	0.000	There's a Difference
	Post-test	4.600	0.503				
Heart	Pre-test	2.000	0.649	2.250	-3.972	0.000	There's a Difference
	Post-test	4.250	0.444				
Sternum	Pre-test	2.150	0.745	2.250	-3.985	0.000	There's a Difference
	Post-test	4.400	0.503				
Diagfragma	Pre-test	2.300	0.470	2.450	-4.056	0.000	There's a Difference
	Post-test	4.750	0.444				
Vertebrae	Pre-test	2.000	0.858	2.500	-4.027	0.000	There's a Difference
	Post-test	4.500	0.513				

*Wilcoxon test
Source: Primary Data, 2021

Based on Table 3, it can be seen that the results of the Wilcoxon test for all variables obtained a p-value of <0.05. The Trivariate Shrinkage CR technique significantly differed in chest anatomical information on geometric radiotherapy verification before and after denoising.

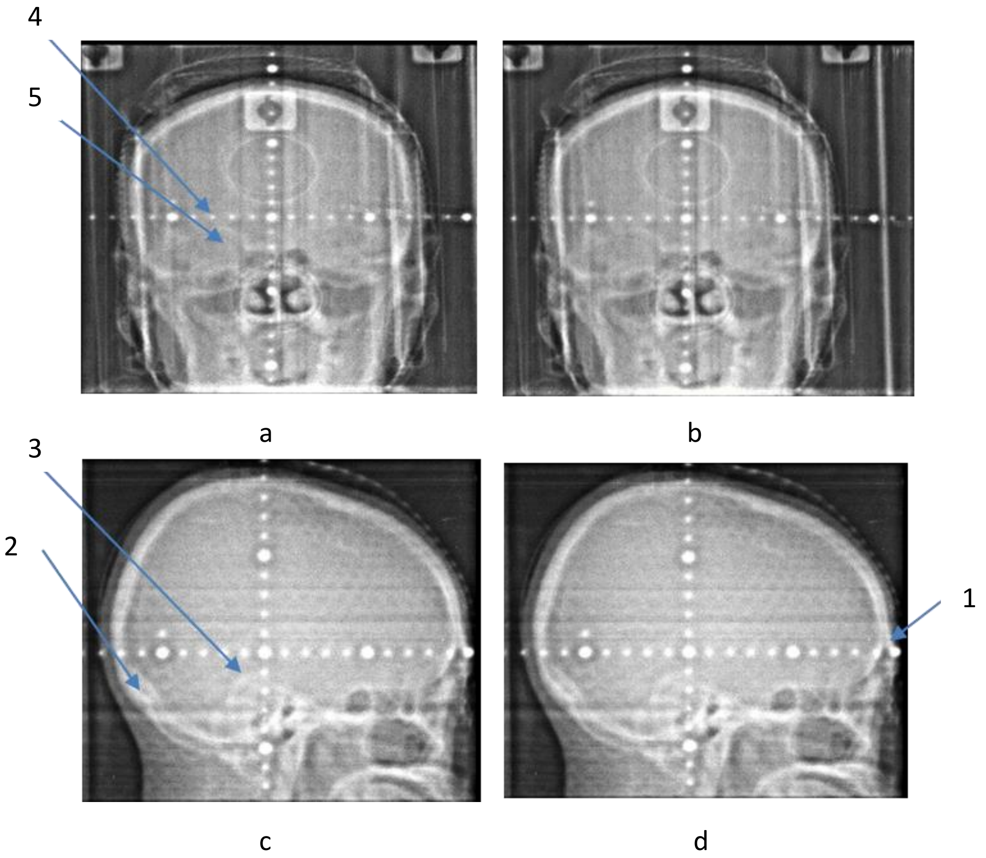

Figure 1. Image results of geometric verification of head and neck projection (AP, Lat)

Information:
a: EPID Lat Image

b: Lat image with Trivariate Shrinkage technique
c: AP EPID image
d: AP image with Trivariate Shrinkage technique
1 : Frontal Sinus
2 : Occiput
3 : Pituitary Fossa
4 : Orbital Ridge
5 : Maxila

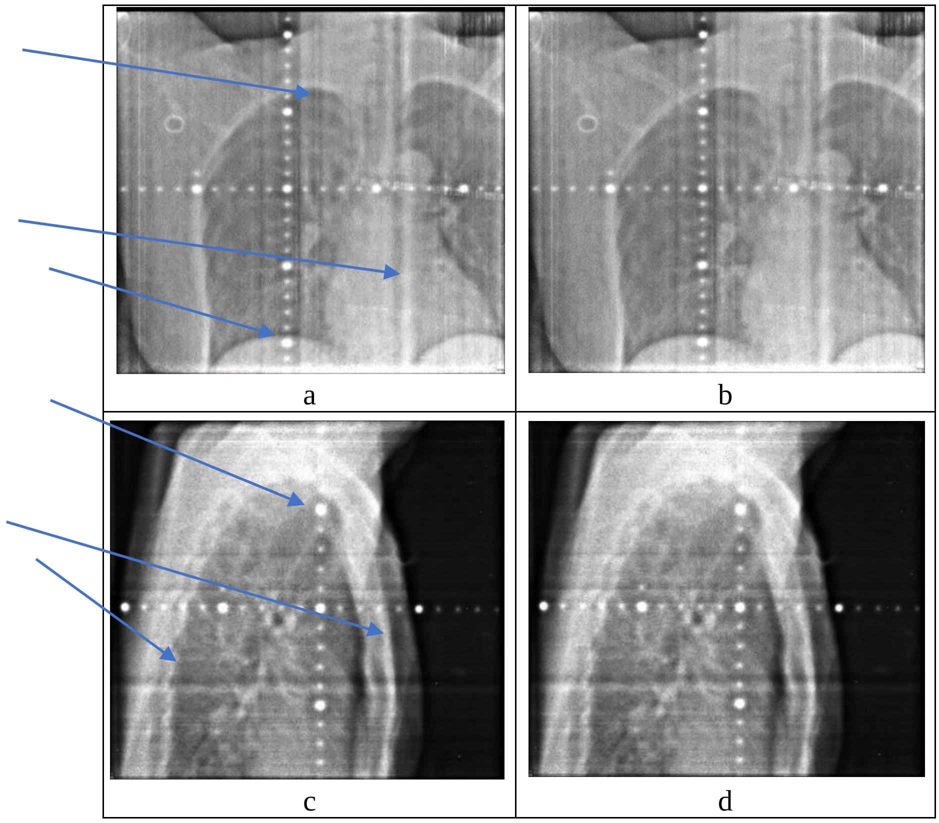

Figure 2. Image results verification geometric chest projection (AP, Lat)

Information:
a: EPID Lat Image
b: Lat image with a technique
c: Citra AP EPID Trivariate Shrinkage c
d: Lat image with Trivariate Shrinkage technique

The results of each assessment of image information were analyzed using the Mann-Whitney test from the overall observer assessment, which aimed to determine the best image information per anatomy on geometric verification of radiotherapy with EPID and after denoising with the Trivariate Shrinkage technique. The following are the results of the Mann-Whitney test on radiotherapy images (head and neck, chest).

Table 4. Analysis of differences between head and neck anatomical information images on EPID and CR after denoising with the Trivariate technique

Variabel	Group	*Mean*	SD	Delta	Z count	*p-value**	Information
Frontal Sinus	CR	4.432	0.501	0.068	-0.637	0.524	It's no
	EPID	4.500	0.506				different
Occiput	CR	4.523	0.505	0.045	-0.426	0.670	It's no
	EPID	4.568	0.501				different
Pituitary Fossa	CR	4.455	0.504	0.023	-0.213	0.831	It's no

Variabel	Group	*Mean*	SD	Delta	Z count	*p-value**	Information
	EPID	4.432	0.501				different
Orbital Ridge	CR	4.386	0.493	0.000	0.000	1.000	It's no
	EPID	4.386	0.493				different
Maxila	CR	4.568	0.501	0.023	-0.213	0.831	It's no
	EPID	4.545	0.504				different
Cervical	CR	4.455	0.504	0.091	-0.862	0.389	It's no
	EPID	4.364	0.487				different

*Mann-Withney Test
Source: Primary Data, 2021

Based on Table 4, it can be seen that the results of the Mann-Whitney test for all variables obtained a p-value of > 0.05. This showed no difference in head and neck anatomical information on geometric verification of radiotherapy with EPID and CR after denoising using the Trivariate Shrinkage CR technique.

Table 5. Analysis of differences between chest anatomical information images on EPID and CR after denoising with the Trivariate technique

Variable	Kelompok	*Mean*	SD	Delta	Z count	*p-value**	Information
Lung Apex	CR	4.650	0.489	0.150	-0.947	0.343	It is no
	EPID	4.500	0.513				different
Sinus	CR	4.600	0.503	0.100	-0.655	0.513	It is no
Gostophrenicus	EPID	4.700	0.470				different
Heart	CR	4.250	0.444	0.150	-1.000	0.317	It is no
	EPID	4.400	0.503				different
Sternum	CR	4.400	0.503	0.100	-0.628	0.530	It is no
	EPID	4.500	0.513				different
Diagfragma	CR	4.750	0.444	0.400	-2.511	0.012	There is a
	EPID	4.350	0.489				difference
Vertebrae	CR	4.500	0.513	0.100	-0.628	0.530	It is no
	EPID	4.600	0.503				different

*Mann-Withney Test
Source: Primary Data, 2021

Based on Table 5, it can be seen that the results of the Mann-Whitney test for diaphragm variables obtained a p-value of < 0.05. This shows a significant difference in diaphragmatic anatomical information in geometric verification of radiotherapy with EPID and CR after denoising using the Trivariate Shrinkage CR technique, where the average diaphragmatic anatomical information for CR is greater than EPID. As for other chest criteria, a p-value of > 0.05 was obtained. This showed no significant difference in chest anatomical information on geometric verification of radiotherapy with EPID and CR after denoising using the Trivariate Shrinkage CR technique.

3.2. Discussion

3.2.1 Results of calculation of image MSE value on geometric verification of radiotherapy that has been denoising using Trivariate Shrinkage CR technique

Based on the results of MSE calculations from radiotherapy geometric verification images (head and neck, chest) with CR after denoising with the Trivariate Shrinkage technique, head and neck image objects with AP projections showed MSE values of 0.4716 and lateral projections showed MSE values of 0.6005. While the Chest object with AP projection shows the result of an MSE value of 0.7127. In contrast, the lateral projection shows an MSE value of 0.6903, and the average result of calculating MSE on geometric radiotherapy verification images (head and neck, chest) with the Trivariate Shrinkage technique indicates an MSE value of 0.6188. The average MSE value in this study was 0.6188, which means it is close to 0, so a good image quality value is obtained.

The MSE value is obtained by comparing the difference values of image pixels denoising on the same pixel, which in the Trivariate Shrinkage technique can give an average squared error value low or close to 0. The smaller the MSE value, the better the image display, while the greater the MSE value, the worse the display on the resulting image (Chaurasia K, 2015). The calculation of MSE in this study is more optimal compared to the previous study by Hakim et al. (2015), compared to shutter using the CLACHE method as denoising on radiotherapy verification images, where calculations with head and neck objects, chests obtained high values of 1298.6 for objects (chest) while 556.5 for objects (head and neck) (Hakim et al., 2015). Research conducted by Sivakumar et al. (2012) showed that applying the Trivariate Shrinkage technique using diagnostic aircraft on radiography computers on head objects is better than filter techniques such as average, median, and unsharp. Judging from the MSE, which is close to 0 (Shukla, 2017).

The low MSE value of Trivariate Shrinkage is obtained because Trivariate Shrinkage has an approach to image restoration by reducing the noise sensitivity of inverted filters. Trivariate Shrinkage can be referred to as an MSE filter because it can minimize the average squared error between the ideal image and the restored image visually. The Trivariate Shrinkage method can cause the image to be smooth, especially in the Gaussian noise type. The noise signal in the digital image on the CR produced by LINAC energy comes from the Modulation Transfer function (MTF) signal, where Trivariate Shrinkage causes the process of decreasing the value of MSE by the original image can suppress speech noise signals from MTF (Yu et al., 2009).

3.2.2 Results of PSNR value calculation of images on geometric verification of radiotherapy that has been denoising using Trivariate Shrinkage CR technique

Based on the results of PSNR calculations from radiotherapy geometric verification images (head and neck, chest) with CR before and after denoising with the Trivariate Shrinkage technique, head and neck image objects with AP projections show PSNR values of 51.8440 dB and lateral projections show PSNR values of 51.1175 dB. While the Chest object with AP projection shows the result of the PSNR value of 49.6656 dB. Meanwhile, the lateral projection shows a PSNR value of 49.6955 dB, the average result of calculating PSNR on the geometric verification image of radiotherapy (head and neck, chest) with the Trivariate Shrinkage technique shows a PSNR value of 50.5806 dB. The average PNSR value in this study was 50.5806 dB, which means that a value of >40dB was obtained for good image quality. PSNR can be compared with the maximum value of the measured signal with the amount of noise that affects the signal. PSNR is used to compare the quality of the cover image (original) denoising. To determine PNSR, first determine the value of MSE; the PSNR value with 30 dB defines relatively low quality, where high image quality is at a value of >40 dB (Isa et al., 2015). The Trivariate Shirinkage technique can provide a PSNR value above >40 Db, which is 50.5806 dB. Using the Trivariate Shrinkage technique can remove noise, and the results of high image quality of PSNR calculations better image quality to eliminate noise. The results of PSNR calculations in this study are better and more optimal than in previous studies, which used CLACHE (George & Joseph, 2017). Another study conducted by Sivakumar et al. (2012) stated that after denoising the results of Computer Radiography diagnostic aircraft images on head objects are better than other filter techniques, for example, Unsharp, median, and average, which are seen from PSNR, which is more than 40 dB (Janaki Sivakumar, Dr.K. Thangavel, 2012).

3.2.3 Differences in anatomical information on geometric verification of radiotherapy before and after denoising using the Trivariate Shrinkage CR technique

Based on the results of the data normality test using the Saphiro-Wilk test, the image results were obtained before and after denoising with the Trivariate Shrinkage technique abnormally distributed or having a p-value below 0.05 from each anatomical criterion of the object (head and neck and chest). So, the Wilcoxon Test was carried out to test the difference in anatomical information on geometric verification of radiotherapy before and after denoising using the Trivariate Shrinkage CR technique. Wilcoxon test results for all head and neck variables obtained a p-value of <0.05. The Trivariate Shrinkage CR technique showed a significant difference in head and neck anatomical information in geometric radiotherapy verification before and after denoising. Wilcoxon test results for all chest variables obtained a p-value <0.05. The Trivariate Shrinkage CR technique showed a significant difference in chest anatomical information in geometric radiotherapy verification before and after denoising.

The results of Wilcoxon's test, specifically per anatomical criteria on head, neck, and chest objects, showed that the image after denoising with the Trivariate Shrinkage technique had a higher average value than before denoising with the Trivariate Shrinkage technique. The difference in image information from both images, both before and after denoising with the Trivariate Shrinkage technique per anatomical criteria, is due to the significantly different visual quality of the image. This can happen because, in the image before denoising with the Trivariate Shrinkage technique, there is noise due to the use of MV energy released by LINAC and the occurrence of the Compton effect, which significantly affects image quality and radiotherapy image information. In the image after-image quality improvement (image processing), using the Trivariate Shrinkage technique can cause reduced noise in radiotherapy geometric verification images. This is supported by the results of Hancheng's (2019) research, which states that the Trivariate Shrinkage technique can suppress noise while maintaining image details with a small size. This is also supported by the results of Min Yin's (2013) research, which states that filter algorithms can effectively remove noise, and the method produces higher objective numerical values and better visual quality (Yin et al., 2013).

3.2.4 Differences in anatomical information on geometric verification of radiotherapy by denoising using Trivariate Shrinkage CR and EPID techniques

Based on the results of the Mann-Whitney test on the overall assessment of the visual observer on the geometric verification image of head and neck radiotherapy with EPID and CR after denoising with the Trivariate Shrinkage technique, it was found that overall, there was no significant difference in the anatomical information of the geometric verification image head and neck radiotherapy with EPID and CR after denoising with Trivariate Shrinkage technique (p-value > 0.05). This shows no visual difference between EPID and CR after denoising with the Trivariate Shrinkage technique from the head and neck anatomical information.

Based on the results of the Mann-Whitney test for diaphragm variables, a p-value of < 0.05 was obtained. This showed a significant difference in diaphragmatic anatomical information in geometric verification of radiotherapy with EPID and CR after denoising using the Trivariate Shrinkage CR technique, where the average diaphragmatic anatomical information for CR is greater than EPID. As for other chest criteria, a p-value of >0.05 was obtained. This showed no significant difference in chest anatomical information on geometric verification of radiotherapy with EPID and CR after denoising using the Trivariate Shrinkage CR technique.

In addition to the Radiation Oncologist's visual assessment, image repair performance resulting (image processing) denoising using the Trivariate Shrinkage technique is evaluated by looking at MSE and PSNR values for optimal image quality assessment. The operation of the image quality algorithm is performed by removing noise from damaged images by inserting Trivariate Shrinkage-based wavelet-based shrinkage filters with spatial-based bilateral joint filters. [13] Trivariate Shrinkage can filter noise and give a different look to the image. The purpose of this filter is to reduce the average squared error as much as possible and reduce noise (Sumit & Raokhande, 2012). Denoising with Trivariate Shrinkage according to research conducted by Sivakumar et al. (2012) on x-ray images of radiography computed heads, the performance of Trivariate Shrinkage shows very significant noise removal, which is measured both in MSE and PSNR as well as in visual images (Sinaga, 2017). Research conducted by Roberts Stanley (2016) observed the comparison of anatomical information of radiotherapy images between EPID and CR, where the application of CR in geometric verification of radiotherapy was able to compensate for EPID, although CR was able to develop EPID visually, but noise quality was still high in CR (Roberts &; Stanley, 2016).

The limitations of this study using the Trivariate Shrinkage technique to perform denoising still have not been tested for precision, accuracy, and sensitivity as well as display enhancement so that it can facilitate both Radiation Oncologists, Medical Physicist, and Radiation Therapist in running the Trivariate Shrinkage image program.

4. Conclusion

The effectiveness of the Trivariate Shrinkage Computer Radiography (CR) technique on image quality and anatomical information on geometric radiotherapy verification obtained a p-value of <0.05 and there was no difference in anatomical information on geometric verification of radiotherapy denoising using Trivariate Shrinkage on CR compared to EPID obtained p-value >0.05. It is hoped that future studies can use the Trivariate Shrinkage technique to produce optimal images and fix the procedure because the resulting denoising is good. The application of this study also uses geometric verification of radiotherapy using CR, which can provide good anatomical information and images comparable to EPID.

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References

Chaurasia K, S. N. (2015). Performance Evaluation and Comparison of Different Noise, Apply on PNG Image Format Used in Deconvolution Wiener Filter (FFT) Algorithm. *Evol Trends Eng Technol*, *4*, 8–14. https://doi.org/doi:10.18052/www.scipress.com/etet.4.8

Dragun, A. E. , Schilling, P. J. , S. T. W. , Kong, F.-M. , Wang, J. , Hricak, H. , & Salanitro PR. (2013). Encyclopedia of Radiation Oncology. *Encycl Radiat Oncol*. https://doi.org/doi:10.1007/978-3-540-85516-3

Dyer, B. A., Jenshus, A., & Mayadev, J. S. (2019). Integrated skin flash planning technique for intensity-modulated radiation therapy for vulvar cancer prevents marginal misses and improves superficial dose coverage. *Medical Dosimetry*, *44*(1), 7–10. https://doi.org/10.1016/j.meddos.2018.01.003

George, S., & Joseph, S. (2017). *Survey on Various Image Deblurring Technique*. *6*(4), 2015–2017.

Hakim, A., K.T.V, T., Harsh, R., & Verma, D. (2015). Effective Processing and Analysis of Radiotherapy Images. *Signal & Image Processing : An International Journal*, *6*(2), 29–44. https://doi.org/10.5121/sipij.2015.6203

Isa, I. S., Sulaiman, S. N., Mustapha, M., & Darus, S. (2015). Evaluating Denoising Performances of Fundamental Filters for T2-Weighted MRI Images. *Procedia Computer Science*, *60*(1), 760–768. https://doi.org/10.1016/J.PROCS.2015.08.231

Janaki Sivakumar, Dr.K. Thangavel, P. S. (2012). Computed Radiography Skull Image Enchancement Using Wiener Filter. *Proceedings of the International Conference on Pattern Recognition, Informatics and Medical Engineering*.

Page, B. R., Hudson, A. D., Brown, D. W., Shulman, A. C., Abdel-Wahab, M., Fisher, B. J., & Patel, S. (2014). Cobalt, linac, or other: What is the best solution for radiation therapy in developing countries? *International Journal of Radiation Oncology Biology Physics*, *89*(3), 476–480. https://doi.org/10.1016/j.ijrobp.2013.12.022

Roberts N, & Stanley S. (2016). An observer study: Comparison of computed radiography to electronic and film portal imaging. *J Radiother Pract*, *5*(4), 197–202. https://doi.org/doi:10.1017/S1460396906000288

Roberts, N., & Stanley, S. (2016). An observer study: Comparison of computed radiography to electronic and film portal imaging. *Journal of Radiotherapy in Practice*, *5*(4), 197–202. https://doi.org/10.1017/S1460396906000288

Ryangga, D. (2011). Optimasi Pencitraan Lokalisasi Dengan Computed Radiografi (CR) Pada Pasien Radioterapi Dengan Berkas Sinar-X 6 MV. *Tesis*, 16.

Shukla, K. N. (2017). A Review on Image Enhancement Techniques. *International Journal of Engineering and Applied Computer Science*, *02*(07), 232–235. https://doi.org/10.24032/ijeacs/0207/05

Sinaga, R. D. (2017). PERBANDINGAN METODE WIENER FILTER DAN TRIVARIATE SHRINKAGE UNTUK MEMPERBAIKI KUALITAS CITRA DIGITAL. *KOMIK (Konferensi Nasional Teknologi Informasi Dan Komputer)*, *1*(1). https://doi.org/10.30865/KOMIK.V1I1.511

Sinecen, M. (2016). Digital Image Processing with MATLAB. *Applications from Engineering with MATLAB Concepts*, 1–42. https://doi.org/10.5772/63028

Sumit, A., & Raokhande, P. (2012). Image Denoising Using Trivariate Shrinkage Filter In Wavelet Domain. *Int J Emerg Technol Adv Eng*, *1*(3), 18–23.

Vyas, A., Yu, S., & Paik, J. (2018). Image Restoration. In *Wiley Interdisciplinary Reviews: Computational Statistics* (Vol. 1, Issue 1, pp. 133–198). https://doi.org/10.1007/978-981-10-7272-7_5

Whittington, R. (2002). Verification of prostate treatment setup using computed radiography for portal imaging. *Journal of Applied Clinical Medical Physics*, *3*(2), 88. https://doi.org/10.1120/1.1457205

Yin, M., Liu, W., Zhao, X., Guo, Q. W., & Bai, R. F. (2013). Image denoising using trivariate prior model in nonsubsampled dual-tree complex contourlet transform domain and non-local means filter in spatial domain. *Optik*, *124*(24), 6896–6904. https://doi.org/10.1016/j.ijleo.2013.05.132

Yu, H., Zhao, L., & Wang, H. (2009). Image denoising using trivariate shrinkage filter in the wavelet domain and joint bilateral filter in the spatial domain. *IEEE Transactions on Image Processing : A Publication of the IEEE Signal Processing Society*, *18*(10), 2364–2369. https://doi.org/10.1109/TIP.2009.2026685

Zukauskaite, R., Hansen, C. R., Grau, C., Samsøe, E., Johansen, J., Petersen, J. B. B., Andersen, E., Brink, C., Overgaard, J., & Eriksen, J. G. (2018). Local recurrences after curative IMRT for HNSCC: Effect of different GTV to high-dose CTV margins. *Radiotherapy and Oncology*, *126*(1), 48–55. https://doi.org/10.1016/j.radonc.2017.11.024