Optimization dose and image quality enhancement of ct scan with back projection filters on the use of automatic exposure control

L Fitriana¹, K Adi², J Ardiyanto³

¹Department of Radiologic Imaging Technology, Universitas Muhammadiyah Purwokerto, KH Ahmad Dahlan Street, Banyumas 53182, Indonesia
²Diponegoro University, Prof Sudarto Street No 13, Semarang 50275, Indonesia
³Departement of Radiodiagnostic and Radioteraphy Technic, Poltekkes Kemenkes Semarang, Tirto Agung Street, Semarang 50268, Indonesia

Corresponding author: lutfatul03@gmail.com

Abstract. Dose and image quality are two important parameters in CT Scan examination. The radiation dose produced at the CT scan is far greater than the radiation dose of the conventional radiological examination, so the utilization must be as good as possible. On Siemens CT Scan there is an automatic exposure control software, with expectations that the radiation dose received by the patient can be reduced because the software is an auto mA that is adjusted to the thickness of the object, but the impact of using the software causes a decrease in image quality, so it needs to be done image improvement using a back projection filter (BPF). Experimental research by applying a back projection filter to the Scan Head image on axial sections. Image assessment using 2 radiologists with data analysis using statistical processing and image post processing. CT Scan image information Head axial pieces experience differences in image information between before and after the back projection, with the mean value in each group experiencing an increase in image quality in the group after a back projection filter. Where the image after the back projection filter by applying automatic exposure control with kV 110 is the most optimal kV.

1. Introduction
Concerns about CT scan are image quality and radiation dose. The radiation dose produced by the CT Scan has now become a special concern because the radiation dose of the CT Scan examination is much greater compared to conventional examinations. The effective dose produced on CT scan is around 2 mSv - 20 mSv per examination, whereas on conventional radiological examination the effective dose produced is <0.1 mSv - 1.5 mSv [1].

In the CT scan there are several factors that can affect the radiation dose [2][3] include tube voltage (kV), mAs, gantry rotation, slice thickness, pitch, and distance of the tube to the CT Scan isocenter. These factors are a complex combination that can affect the radiation dose, but the factors that are very important in producing radiation doses and affect image quality are kV and mA values. The kV value influences the amount of x-ray emission produced to penetrate the object, kV determines the maximum bremstrahlung radiation so that it affects the quality of the ray radiation, while the mA value affects the number of electrons moving from the cathode to the anode per unit time. kV and mA are the main factors...
affecting radiation dose, noise and SNR. The higher the kV and mA values, the better the resolution and contrast resolution and the lower the noise, but the greater the resulting dose value [3].

CT Scan aircraft manufacturers do various ways to reduce the CT Scan radiation dose, one of them is tube current modulation. On the Siemens CT Scan aircraft there is an auto mA adjustment software facility, also called Care dose. Care dose is an automatic exposure control (AEC), which ensures constant quality diagnostic images of all parts of the body at the lowest possible dose. Auto mAs software is designed to reduce radiation doses by changing mAs based on the size of the patient's body and attenuation automatically. In the CT scan auto mA software is highly recommended to be used, because the software can reduce the radiation dose up to 40% to 50% on the CT scan [4].

One of the CT scans that is often done is the CT Scan of the Head, the most common indication for a CT scan is a fracture. Fractures that often occur on the head that is in the cranium base region, fractures on the cranium base relatively often occur almost 3.5 - 24% in cases of head trauma [5]. In the case of cranium base fractures, CT Scan is the primary choice in presenting the anatomical features of the cranium base and evaluating fractures on the cranium base, besides CT scanning is also more sensitive in detecting fibroosseous lesions, calcifications and sclerosis. On CT scan cranium bases with fracture cases a high resolution is needed so that it can show up to small fractures [5][6].

To get high image resolution it is necessary to obtain spatial resolution, good contrast resolution and low noise by using high exposure factors (kV and mA). By using auto mA, the mA value is obtained automatically by adjusting the thickness of the patient's body so that the resulting radiation dose can be reduced according to the patient's body condition [7]. But keep in mind that with the reduction in the tube current value (mAs) there will be an increase in noise. Therefore optimization of mAs values must be managed carefully with an alternative approach that is using noise reduction algorithms to reduce noise and spatial resolution that is still good [8]. One method of noise reduction is the back projection filter image processing method. Algorithm back projection filter is seen as a useful and efficient method of reconstruction in CT scan images. The effect of this filter is also important for getting good image quality after reconstruction [9].

2. Methods
This type of research is a quasi comparative (categorical-numerical) paired experiment using a Pretest Posttest Without Control Group Design research design. The study was carried out on CT images of axial cut heads using head phantom with kV parameters varying 80 kV, 110 kV and 130 kV, the mAs values were obtained automatically by activating the 4D care dose software on the Siemens CT Scan plane, Pitch 0.5. The radiograph images assessed by radiologist are the base cranium, especially in the clivus, foramen ovale, anterior clinoid, carotid canal, foramen spinosum, pterygopalatine fossa and optic canal. This study aims to determine differences in radiation dose and image quality of CT Scan Head axial cuts between before and after using the back projection filter and applying automatic exposure control.

3. Result and discussion
In figure 1, it can be seen that there are differences in the value of the dose in the use of care dose and without the use of care dose in each variation in the kV value. The results of the radiation dose obtained are by looking at the CTDIvol value on the CT Scan monitor screen after scanning is complete. At kV 80 without using care dose the value of the radiation dose obtained is 32.98 mGy, whereas in the use of care dose the value of the radiation dose obtained is 13.99 mGy. In the use of kV 110 without using the care dose the resulting radiation dose is 44.84 mGy, whereas in the use of care dose the value of the radiation dose produced is 25.85 mGy. In the use of kV 130 without using a care dose the value of the resulting radiation dose is 56.47 mGy and using a care dose value of the resulting radiation dose is 37.48 mGy. From these data it can be seen the difference in radiation dose values in each variation of the kV value with and without using care dose, where all groups using care dose have lower radiation doses compared with groups without using care dose.
Assessment of the difference in radiation doses produced between groups using and without using automatic exposure control is done descriptively, with the following distribution:

![Radiation Dose](image)

**Figure 1.** The result of radiation dose between using care dose and without care dose

In the graph above it can be seen that there are differences in the value of the dose in the use of care dose and without the use of care dose in each variation in the kV value. The results of the radiation dose obtained are by looking at the CTDI\text{vol} value on the CT Scan monitor screen after scanning is complete. At kV 80 without using care dose the value of the radiation dose obtained is 32.98 mGy, whereas in the use of care dose the value of the radiation dose obtained is 13.99 mGy. In the use of kV 110 without using the care dose the resulting radiation dose is 44.84 mGy, whereas in the use of care dose the value of the radiation dose produced is 25.85 mGy. In the use of kV 130 without using a care dose the value of the resulting radiation dose is 56.47 mGy and using a care dose value of the resulting radiation dose is 37.48 mGy. From these data it can be seen the difference in radiation dose values in each variation of the kV value with and without using care dose, where all groups using care dose have lower radiation doses compared with groups without using care dose.

Assessment of differences in head CT (SNR) image quality was assessed from paired T-test between groups before and after a back projection filter was performed on each variation of kV (80 kV, 110 kV and 130 kV). The SNR value is obtained from the ratio between mean HU and the standard deviation of the same ROI, this study uses radiant software to calculate SNR. From the paired T-test results in all groups obtained p-value <0.05, which means there are differences in image quality between groups before and after a back projection filter, and to find out the treatment group that has the highest SNR can be seen in the table below:

| kV Variation | Mean±SD Before back projection filter | Mean±SD After back projection filter |
|--------------|--------------------------------------|--------------------------------------|
| kV 80        | 0.353±2.089                          | 1.752±0.739                          |
| kV 110       | 1.148±1.096                          | 2.158±0.947                          |
| kV 130       | 1.014±1.028                          | 2.391±0.897                          |

From the table above it can be seen that the SNR value has increased in all variations of the kV value after the back projection filter image processing method is performed. The highest SNR value is in the kV 130 treatment group after image processing, and the lowest SNR value is in the kV 80 treatment group before the image processing method.
To find out the optimal results from the three treatment groups, namely: 80 kV after the image processing method, 110 kV after the image processing method and 130 kV after the image processing method is performed again the friedman test is performed to see the mean rank value based on the assessment results from the radiology doctor, so that it can be seen the most optimal kV value based on the quality of the SNR value and also seen from anatomic information based on the assessment of radiology. Friedman test results mean value in the treatment groups kV 80, 110 and 130 after the image processing method can be seen in the table 2.

![Figure 2. kV 80 before BPF (a). kV 110 before BPF (b). kV 130 before BPF (c). kV 80 after BPF (d). kV 110 after BPF (e). kV 130 after BPF (f)](image)

Table 2. Friedman test results of anatomic information on the data group after the image processing method BPF

| Group         | Mean Rank |
|---------------|-----------|
| kV 80 Post BPF| 1,00      |
| kV 110 Post BPF| 2,50    |
| kV 130 Post BPF| 2,50    |

From table 2 above it can be seen the ranking values of kV 110 and kV 130 after the image processing method has the same mean rank value of 2.50. While kV 80 after image processing has the lowest mean rank value, namely: 1.00. This can be interpreted that the radiologist's assessment of image information in the kV 110 and kV 130 groups after the image processing method has or can display the same anatomic information.

In this study there are differences in radiation doses in the variation in kV values with and without using a care dose, where the radiation dose produced on the use of a care dose is much less than without using a care dose. This is due to the value of mAs generated in the use of care dose is obtained by activating the care dose software on the CT Scan Siemens 16 Slice which will then automatically generate mAs in accordance with the thickness of the object being examined (161 mAs). Whereas the mAs value without using care dose is obtained from routine parameters of CT examination in the hospital (240 mAs).

From these results it can be seen that the use of mAs (tube currents) affects the dose of radiation produced. The higher the mAs the radiation dose produced will be greater, and conversely the lower the mAs the lower the radiation dose produced. That is because the mAs value or tube current is an important parameter in the CT Scan modality, when the x-ray tube current increases, the number of x-ray photons...
produced increases and the resulting x-rays will increase so that the radiation dose received is greater. In the use of care dose, the production of X-ray tubes (mAs) produced is based on the size of the object and the attenuation of the object traversed. mAs increases in parts of the body with large attenuation and mAs decreases in parts of the body with small attenuation, such as soft tissues, so that the average mAs of the object is obtained, with the expectation that the dose received by the patient is according to his needs, not less or not more [10].

The radiation dose received by the body, no matter how small, always has an impact on changes in the body's biological system, both at the molecular level and at the cellular level. The effects of radiation can be divided into stochastic effects and deterministic effects. Stochastic effects are effects that occur due to radiation exposure at doses that cause cell changes, whereas deterministic effects do not have a threshold dose that causes cell death due to radiation exposure to the body. So as much as possible in conducting CT scans as much as possible to provide the lowest possible radiation. As the concept of ALARA (As Low As reasonably Achievable) by utilizing the lowest possible radiation by getting optimal results, one of which is the optimization of factors that can affect the radiation dose. In this study, the researchers optimized the kV and mAs values (using care dose) to obtain acceptable image results [11].

The difference in the SNR values of the two images both before and after the overall anatomical back projection filter was performed due to the significantly different visual quality of the image. This can occur because in the image before the back projection filter is carried out there is noise due to the acquisition process of the CT Scan image itself. Noise on CT Scan can occur as a result of the process of acquisition (acquisition) of the image and transmission errors. Back Projection Filter is seen as useful and efficient in CT Scan image reconstruction. The effect of the filter is also very important to improve good image quality after reconstruction [12].

After knowing that the SNR value after the back projection filter image processing method has increased the SNR value in all variations of the kV value. Then the firedman test was performed again to see the mean rank value based on the results of the assessment from the radiologist, which can be concluded that the kV 110 can be said to be the optimal kV due to the kV 110 after the image processing method, the results of the doctor's reading stated that the anatomic information produced the same or no different from the use of kV 130 after the image processing method. Whereas in terms of the radiation dose received, using kV 110 is much lower, at 25.85 mGy while using kV 130, the resulting dose is: 37.48 mGy.

4. Conclusion

Based on the results and discussion in this study, it can be stated that the kV value of 110 can be said to be the optimal kV due to the kV 110 after the image processing method is carried out, from the doctor's reading results that the anatomic information produced is the same or no different from the use of kV 130 after the image processing method. Whereas in terms of the radiation dose received, using kV 110 is much lower, at 25.85 mGy while using kV 130, the resulting dose is: 37.48 mGy. The BPF technique efficiently maintains texture, suppresses noise, and the use of care dose is very necessary because it can reduce the radiation dose produced.

References
[1] Bauhs J A, Vrieze T J, Primak A N, Bruesewitz M R and McCollough C H 2008 RadioGraphics 28 1 245-253
[2] Zacharias C, Alessio A M, Otto R K, Iyer R S, Philips G S, Swanson J O and Thapa M M 2013 American Journal of Roentgenology 200 5 950-6
[3] Andriani I and Anam C 2012 Penentuan Ct Dose Index (Ctdi) Untuk Variasi Slice Thickness Dengan Program 15 3 69-76
[4] Raman S P, Johnson P T, Deshmukh S, Mahesh M, Grant K L and Fishman E K 2013 Journal of the American College of Radiology 10 1 37-41
[5] Bobinski M, Shen P Y and Dublin A B 2016 Basic Imaging of Skull Base Trauma 381-7
[6] Myga-Porosito J, Skrzelewski S, Sraga W, Borowiak H, Jackowska Z and Kluczewska E 2011 *Polish Journal of Radiology* **76** 1 41-51

[7] Goldman A R 2013 *Reducing Radiation Dose in Body CT: A Primer on Dose Metrics and Key CT Technical Parameters* April 741–7

[8] Anam C, Haryanto F, Widita R, Arif I, Dougherty G and Mclean D 2018 *Volume computed tomography dose index (CTDI vol) and size-specific dose estimate (SSDE) for tube current modulation (TCM) in CT scanning* **16** 3

[9] Kidoh M 2016 *Impact of Knowledge-Based Iterative Model Reconstruction in Abdominal Dynamic CT With Low Tube Voltage and Low Contrast Dose* April 687–693

[10] Goldman L W 2019 *Principles of CT: Radiation Dose and Image Quality* 213–226

[11] Strauss K J and Kaste S C 2006 *The ALARA (as low as reasonably achievable) concept in pediatric interventional and fluoroscopic imaging: striving to keep radiation doses as low as possible during fluoroscopy of pediatric patients-a white paper executive summary* **36** 110–2

[12] Hussani M T Al, Ali M H and Hayani A 2014 *The Use of Filtered Back projection Algorithm for Reconstruction of tomographic Image* **17** 2 151–6