Accuracy of bleeding volumetric measurement on head CT scan with sequence and helical techniques using manual and automatic methods: A phantom study

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ABSTRACT

Introduction: There are two data acquisition methods for computed tomography (CT) scans, namely sequence and helical. Each of them has two ways of measuring the volume of bleeding in a head CT scan, namely by manual and automatic methods. So, it is necessary to have an analysis for measurement accuracy with these two methods in two data acquisitions. The purpose of this study was to compare and evaluate bleeding volumetric measurement accuracy of sequence and helical on head CT acquisition using manual and automatic methods.

Materials and Methods: This is quantitative research with a true experimental approach. Actual bleeding volume was simulated by an acrylic phantom containing Iodine contrast media (5 ml, 10 ml, 15 ml, and 20 ml). The phantom was scanned using routine CT protocol using the helical and sequence technique. Bleeding volume from each technique was measured manually using the Broderick formula and automatic software (ROI based). Accuracy was assessed by comparing the volume measurement result to the actual bleeding volume. Data was analysed using the Friedman test and by Wilcoxon.

Results: The standard deviation of measured bleeding volume from the manual and automatic measurements compared to the actual bleeding volume were (0.220; 0.236; 0.351; 0.057) and (0.139; 0.270; 0.315; 0.329) in helical technique, and (0.333; 0.376; 0.447; 0.476) and (0.139; 0.242; 0.288; 0,376) in sequence technique. There are differences in the measurement results from the helical and sequence techniques ($p < 0.05$) and using manual and automatic methods ($p < 0.05$).

Conclusion: The measurement of bleeding volume that has a standard deviation value compared to the actual volume is more accurate in the helical technique using the automatic method, while the sequence technique is the manual method.

KEYWORDS:
Bleeding volumetric measurement; head CT; helical; sequence

INTRODUCTION

Computed tomography (CT) scan is a fast and accurate imaging modality in diagnosing abnormalities in the head or brain.[1] It is very useful for emergency cases and the gold standard for brain injury and trauma brain injury (TBI) evaluation.[2] CT is the first-line modality of choice for evaluating the brain and the most often performed CT examination in many hospitals nowadays. CT scan is the first and foremost modality in the investigation of head trauma patients.[3] In some cases of suspected paediatric non-accidental trauma, skull radiographs are still performed as part of a skeletal survey in addition to CT, however this does not supplant the need for CT when TBI is clinically suspected. Although radiographs may help differentiate accessory sutures from fractures, this too may become obsolete as three-dimensional skull reformats are increasingly available in clinical practice.[4]

CT scans of the brain can be performed using either sequence or helical CT scanning techniques. In sequence scanning, the CT table moves through the rotating gantry, which images thin slices of the brain. Because the table advances only after each slice is scanned, this technique is time-consuming prone to potential misregistration and motion artifacts and has limited availability of the overlapping images used for postprocessing. In helical scanning, the CT table moves through the gantry at a constant speed as scanning occurs, resulting in faster scan times, continuous data acquisition, and continuous radiation.[5] This technique reduces the scan time, and with breath-hold technique can reduce the motion artifacts. Data acquisition in the helical technique is continuous, which results in an improvement in the post-processing of MPR and VRT reconstructions. It is not clearly stated that the helical CT produces such good-quality images to replace those of conventional CT. For example, studies have revealed that the axial technique yields better image quality, especially in structures with low contrast differences yet another study has shown that the two techniques attribute similar image quality. In addition, there are studies suggesting that the helical technique has a lower dose whereas others show the exact opposite.[6]

Bleeding in the brain due to trauma or stroke is one thing that requires evaluation to measure its volume. Intracranial

This article was accepted: 17 November 2023
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haemorrhage (ICH) that causes mass effect usually needs urgent neurosurgical evacuation. It is divided into five subtypes including intraventricular haemorrhage (IVH), intraparenchymal haemorrhage (IPH), subarachnoid haemorrhage (SAH), epidural haemorrhage (EDH), and subdural haemorrhage (SDH). The decision for surgical intervention for craniotomy is dependent on the injury type and the patient's neurologic exam. Only three potential subtypes of ICH that may necessitate surgical interventions: intraparenchymal haemorrhage (IPH), subdural haemorrhage (SDH), and epidural haemorrhage (EDH).[2] Head bleeding can occur in several places such as ICH, SAH, EDH and SDH. The location and volume of the bleeding can determine the mortality rate. So, accuracy in measuring bleeding volume with an easy and accurate method is important.[7]

Measurement of bleeding volume can use two methods, namely manual and automatic. Manually using the Broderick method and automatically using analyse software, the region of interest (ROI) was segmented from surrounding regions automatically by setting up threshold levels.[8] The Broderick method is performed by multiplying the bleeding diameter to the total length of the slice thickness. The automatic method calculates the volume by identifying the HU values in the bleeding area with volume evaluation software. The aim of this study was to compare and evaluate the bleeding volume measurement of sequence CT and helical CT of the brain using automatic and manual methods with standardised phantom.

MATERIALS AND METHODS

Study Design and Data Collection

This study was conducted in Roemani Muhammadiyah Hospital. This is an experimental study that analyses of actual bleeding volume simulated by an acrylic phantom with four tube sizes (diameter= 2 cm) containing iodine contrast media. Actual bleeding volume was simulated by an acrylic phantom as shown in Fig 1 with four tube sizes (diameter= 2 cm) containing iodine contrast media. The tube volume is 5 ml, 10 ml, 15 ml, and 20 ml respectively. The whole size of the phantom is 20 cm in diameter and 11 cm in thickness corresponds to the size of the average adult human head.

Preliminary Scanning

Preliminary scanning is performed to figure out the best filter. Filter H70s was chosen to get the best image contrast.

Radiological Data

Scanning was performed using six slice CT-scan (Siemens Emotion) with a routine head protocol (rotation time 1 second and slice thickness 2.5 mm, 130 kV; 250 mAs; 200 mm FOV; H70s filter; Hu min: 3069; HU max: 3071. Scanning for each tube volume (5 ml, 10 ml, 15 ml and 20 ml). Volume measurements repeated three times.

Measurement of bleeding with manual method (Fig 2A):

a. Slice selection: The 10th slice (the middle slice number). This slice representing the middle position of the entire length of the slices. The slice selection for the length measurement is give two measurements, the first measurement at the greatest diameter of the slices, and then the second measurement perpendicular to the first measurement.
b. Measure the thickness of bleeding with the Broderick formula:

    Volume = A x B x C / 2
    A = long diameter of bleeding
    B = diameter of bleeding width
    C = thickness of bleeding

Thickness of bleeding is the number of slices in which the bleeding is visualized multiplied by the slice thickness

Measurement of bleeding automatic method (Fig 2B):

a. Selection of the area in upper and lower limits of the lateral scan.
b. Apply the circle tool to the bleeding area in the axial image.
c. Determine the HU value for upper HU and lower HU (minimum HU value is 3069, maximum HU is 3071).

Data was analysed with the Friedman test followed by Wilcoxon (confidence level= 95%). Accuracy was assessed from the standard deviation value of the measurement results to the actual volume.

RESULTS

The results of measuring volume of bleeding on a head CT scan in the helical technique and sequence within manual and automatic measurement methods.

The results of calculating the helical technique using the manual method mean that the average value close to the actual volume in the helical technique is at a volume of 5 ml (4.39 cm^3) and 15 ml (11.40 cm^3). Whereas in the helical technique the automatic method is at a volume of 10 ml (8.09 cm^3) and 20 ml (18.93 cm^3) as shown in Table I.

The results of the helical technique calculation study using manual and automatic methods were carried out by means of a paired samples T-test with a significance value of 5 ml volume 0.000, 10 ml volume 0.000, 15 ml volume 0,001 and 20 ml volume 0.021 ($p < 0.05$). It can be concluded that there is a significant difference in the helical technique using automatic and manual methods as shown in Table II.

The results of the research on calculating the sequence technique using manual and automatic methods were carried out by the means of a paired samples T-test with the results of a significance value of 0.000 5 ml volume, 0.000 10 ml volume, 0.012 15 ml volume and 0.000 20 ml volume ($p < 0.05$). It can be concluded that there are significant differences in the sequence technique using automatic and manual methods as shown in Table II.

The automatic method has a smaller standard deviation in the helical technique, while the manual method with a volume of 5 ml has the same value, namely the standard deviation value is 0.139. Whereas at 10 ml, 15 ml and 20 ml, it is smaller in the sequence technique than the helical technique as shown in Table III.

Table I: The average value of bleeding volume using manual and automatic methods within helical and sequence scan modes

Volume	Helical		Sequence	
	Manual (cm^3)	Automatic (cm^3)	Manual (cm^3)	Automatic (cm^3)
5 ml	4,39	4,10	4,39	3,75
10 ml	7,87	8,09	8,05	7,27
15 ml	11,40	11,12	11,72	10,35
20 ml	15,05	18,93	14,20	13,55

Table II: Paired samples T-test result of bleeding volume using manual and automatic

Volume	Helical		Sequence	
	Sig. Value	p value	Sig. Value	p value
5 ml	0,000	< 0,05	0,000	< 0,05
10 ml	0,000	< 0,05	0,000	< 0,05
15 ml	0,001	< 0,05	0,012	< 0,05
20 ml	0,021	< 0,05	0,000	< 0,05

Table III: Standard deviation value with actual bleeding volume in manual and automatic method

Volume	Manual		Automatic	
	Helical	Sequence	Helical	Sequence
5 ml	0,139	0,139	0,220	0,333
10 ml	0,270	0,242	0,236	0,376
15 ml	0,315	0,288	0,351	0,447
20 ml	0,329	0,376	0,057	0,476

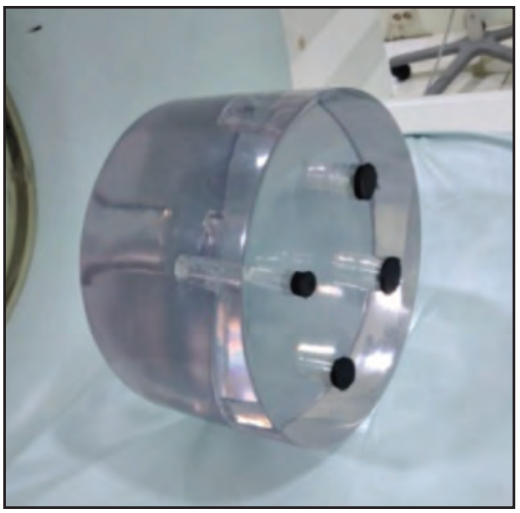

Fig. 1: Acrylic phantom.

DISCUSSION

The results of measuring volume of bleeding on a head CT scan in the helical technique and sequence within manual and automatic measurement methods

CT advantages for assessment of TBI include its sensitivity for demonstrating acute intra-axial and extra-axial haemorrhage, mass effect, ventricular size and bone fractures.[9] Post-traumatic blood may be epidural, subdural, subarachnoid, intraventricular or intraparenchymal. IPH may be related to brain contusion, that is, from injury to brain parenchyma after direct blow against the calvarium, or from diffuse axonal injury, also termed traumatic axonal injury or shear injury. So, it is necessary to have an analysis of the volume of bleeding in head trauma patients through the CT scan modality.[10]

Volume measurement plays an important role in further management, both surgical and non-surgical (conservative). The helical technique is a helical beam geometry that is used to obtain volume in a network. In this technique the x-ray tube is moved around the patient in a helical pattern with each scan. This technique produces a single slice of rotating x-ray tube. The advantage of this technique is relatively fast time.

The range of HU values used is smaller or larger, causing tissue with a smaller or larger HU value than the bleeding HU value to be counted as bleeding. The automatic volume method (SVE) has a longer processing time than the manual method, due to the process of segmenting the bleeding area and determining the HU value according to the type of

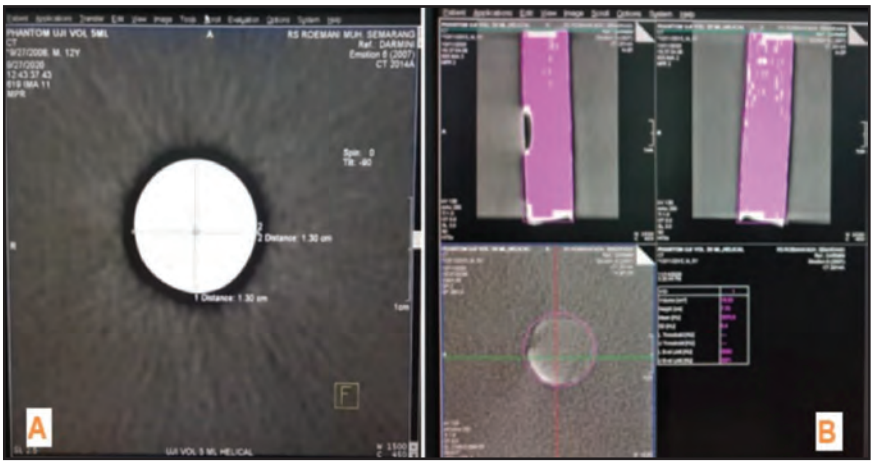

Fig. 2: Measurement of bleeding with manual method (A) and automatic method (B).

bleeding. Volumetric calculation manually (Broderick) looks more complicated according to data and calculations, but it's a process that have a faster processing time. In terms of accuracy, there is a tendency for the volume value of the manual method to be higher because it depends on the shape and size of the bleeding. In breeding with a regular form (regular), the manual method (Broderick) has a very small volume difference value compared to the automatic volume method, the average percentage value of the volume difference is 6%. However, in bleeding with irregular shapes (irregular) and bleeding with more than one point (multilobular) the manual method (Broderick) has a higher volume yield (overestimated) than the automatic volume method, the average percentage of the volume difference is 25%.

According to the researchers, the results in this study used the helical technique, the manual method, the results that were close to the actual size were at 5 ml volume, while in the automatic method, the values that were close to the actual volume were at volumes of 10 ml and 20. The different test results using manual and automatic methods, there were differences. Manual method ABC/2 is accurate with a fast process for bleeding volumes for small ones and there is a significant overestimation error for calculating bleeding volume, especially for irregular bleeding. and multilobular.[11] Volumetric calculations using the automatic volume method which is called Software Volume Evaluation (SVE) are strongly influenced by slice thickness or slice reconstruction, a thinner slice thickness will produce a more accurate volume measurement.[12] Although measurement of bleeding volume is currently mostly done by segmentation technique in ICH, it is still preceded by manual measurement with the ABC/2 formula.[13]

The results of measuring the volume of bleeding on a head CT scan in the sequence technique within manual and automatic measurement methods

In principle, the sequence technique of the X-ray tube and detector moves around the patient and collects data from first to last data points. Then the patient moves to the second position and the scan takes place automatically. Sequence technique is often called the axial scanning technique. During scanning the x-ray tube rotates around the patient to generate a specific set of data. To get another picture, the examination table must move to another position and set of data to produce images.[6]

The results of measuring the volume of bleeding in this study in the sequence technique, the values obtained are close to the actual volume using the manual method. This is consistent with that statement ABC/2 method is a valid method for estimation of ICH volume for both regular and irregular shaped hematomas.[14]

The standard deviation value of the measurement results of the bleeding volume of the sequence and helical techniques was compared with the actual volume

The automatic method has a smaller standard deviation in the helical technique, while the manual method with a volume of 5 ml has the same value, namely the standard deviation value is 0.139. Whereas at 10 ml, 15 ml and 20 ml, it is smaller in the sequence technique.

Data acquisition using the helical technique is volumetric in nature and has the advantage of reducing the radiation dose to patients.[15] Helical technique also has significant advantages over sequential CT techniques and therefore is likely to pave the way for the implementation of spiral CTs in cranial neuroradiology as a standard procedure.[16]

Based on the measurement results of the helical technique, the automatic method has a smaller standard deviation value, while the manual method sequence technique has a smaller standard deviation value. The automatic volume method (software volume evaluation) is a volume calculation by the computer software available on the CT scan tool. This method of volume calculation is used after all the parameters and the scanning process are complete. Calculation of the volume of bleeding based on this method is only used on CT scans with helical or helical techniques.[17] To obtain accurate information about the volume of bleeding it is critical to obtain the location and the shape of the bleeding regions for the diagnosis of cerebral haemorrhage, in which the algorithm needs to be improved.[18] Recently, fully automated algorithm method for measuring bleeding volume has also been developed. The fully automated algorithm quantified ICH volumes significantly faster than the semiautomated

and manual methods. Fully automated ICH segmentation may facilitate therapeutic decision-making and outcome prediction in patients with spontaneous, supratentorial ICH.[19] Several segmentation methods can also be used to estimate the estimated volume of bleeding, such as the Dynamic Graph Convolutional Neural Network (DGCNN) which predicts small-scale intracranial haemorrhage data set although a large dataset would be better.[20] But what is done in this study is to test the accuracy of calculating the volume of bleeding from the volume actual size and measured using the manually and automatically measurement methods within sequential and helical scan mode using a phantom.

This study has an update in discussing sequence and helical scanning techniques in determining the accuracy of bleeding volume measurements using phantom. In several existing studies for sequence and helical techniques often only discuss the radiation dose.[21]

This research has the limitation of not being able to assess masses, oedema, or midline shift. Because this research is a study using a phantom which is designed to simulate bleeding, the measurement of masses, oedema, or midline shift cannot be measured. Further research is needed to simulate irregular bleeding volume measurements, use of slice thickness variations and filter variations.

CONCLUSION

The results of the paired samples T test difference test were significant at 5 ml volume = 0.000, 10 ml volume 0.000, 15 ml volume = 0.012 and 20 ml volume = 0.000 ($p < 0.05$). Standard deviation value of the measurement results of the bleeding volume of the sequence technique and the helical technique compared to the actual volume of the helical technique measurement in the automatic method has a smaller standard deviation value. The most accurate method is the automatic method with the helical technique because it has a smaller standard deviation than the manual method with both techniques.

ACKNOWLEDGMENTS

We acknowledge the research grant received from Poltekkes Kemenkes Semarang with No: HK.02.03/6.1/3939/2020

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