

## Analysis of the Physical Parameters HU, LAC, and HVL for Cerebral Hemorrhage Using CT scan

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### Abstract

The internal structures of the human body are generally invisible; however, various medical imaging techniques can produce images that enable visualization of internal tissues and the diagnosis of abnormal conditions. Computed tomography (CT) is one such medical imaging technique. In this study, a head CT protocol was used to examine a 55-year-old female patient. Mean CT numbers, expressed as Hounsfield units (HU), were extracted from the CT images and analyzed in terms of the linear attenuation coefficient (LAC) and half-value layer (HVL). A slight decrease in the LAC value, accompanied by an increase in the HVL value, was observed in the abnormal region compared with the normal region. Based on the obtained HU, LAC, and HVL values and their comparison with reference values for hemorrhagic lesions, the lesion was identified as an isodense, subacute hematoma.

**Keywords:** Computed tomography (CT), Hounsfield units (HU), linear attenuation coefficient (LAC), half-value layer (HVL), iso-dense.

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### 1. Introduction

The physical universe is composed of matter and energy. All physical processes interact, including medical imaging methods. Medical images are formed by the interaction of x-ray energy with human tissue. When the primary x-ray beam passes through a slice of the body to be examined, the tissues along the beam's path interact with this beam, attenuating the photons from the x-ray beam as they pass through the layers of tissue before reaching the receptor (detector) (Bushberg, et al., 2020). A computed tomography (CT) scanner is a powerful diagnostic medical imaging tool that combines a series of x-ray beams emitted by an x-ray emitter that rotates around the tissue to be examined.

Scanning is the first step in CT scanning, where the diagnostic medical image is formed by covering the x-rays of the organ to be examined (Beaulieu & Dutilleul, 2019; Sprawls, 1995). There are different scanning modes, the most important of which are: Axial/sequential scanning, spiral/helical scanning, and multi-slice scanning. Scanning is performed at a large number of angles using projections across the body called Geometric Projections, which are the data collection architecture of the CT scanner. Many of these have been developed through the development of the device components over the different generations of CT devices, such as: Parallel Beam Projection, Fan Beam Projection, and Cone Beam Projection. Then, the medical

image (Formation of an Image) of the scanned body is formed (Handem et al., 2018). The detector is used to collect the projection data. The detectors receive the data as signals and transmit them to a computer system that performs the image reconstruction for all the resulting arrays (Banjak, 2016). The computer system initially preprocesses the raw data and then uses a CT reconstruction algorithm for all the resulting arrays to produce the CT image using the following methods: back-projection and iterative reconstruction. The CT image reconstruction process first calculates the attenuation coefficient value for each voxel, which is then converted to a pixel value, whose value is numerically determined by the CT numbers. In the reconstructed image, each pixel is represented by a numerical value associated with the linear attenuation coefficient value of the tissue at each voxel, (Dance et al., 2014). Computed tomography numbers (CT numbers), also known as Hounsfield units (in honor of Godfrey Hounsfield), are a set of numbers that measure gray levels numerically by material density or linear attenuation coefficients (Abdulla & Clarke, 2020). Water is used as the reference material to determine CT image numbers; water (a reference material) has a CT number value of zero. Materials with an attenuation coefficient greater than water have a positive CT number value, while materials with an attenuation coefficient less than water have a negative CT number value (Söderberg & Gunnarsson, 2008). Hemorrhagic stroke occurs when a blood vessel in the brain bursts and begins to bleed inside the brain, causing blood to flow into the brain tissue around it, causing damage to brain cells. Also, the brain cells behind the leak do not receive a regular blood supply (Chugh et al., 2009; Kjerland & Lindseth, 2017; Sun, 2005). Its causes are: uncontrolled high blood pressure, treatment with blood thinners (anticoagulants), aneurysm (a small external pocket in the form of a sac or swelling in weak points in the walls of blood vessels that extends outside one of the arteries of the brain), formation of protein deposits in the walls of blood vessels leading to weakness in the vessel wall (cerebral amyloid angiopathy), ischemic stroke that leads to hemorrhage, physical injury (such as a car accident), and a less common cause of bleeding is a fracture or rupture of a blood vessel, which is an arteriovenous malformation (AVM - Arteriovenous malformation) in which some blood vessels have thin walls, leading to their rupture easily (Bazarian et al., 2006)(Putz & Pabst, 2006). There are some types of hemorrhagic stroke determined according to its anatomical location inside the brain, and also there are types of hemorrhagic stroke according to medical image by comparing the resulting values with the reference HU value for the CT scan (Brain parenchyma) less than or equal to (30-40 HU). For CSF, it ranges between (0 and 15 HU), and the hemorrhagic cells have (less than 80 HU). Thus, bleeding can be classified based on the analysis of the

medical CT image into three types: acute hematoma (a lesion has higher density than the normal brain (hyperdense) more than 40 HU and appears in the image whiter than the normal brain, the recent blood = (60-90) HU (bleeding)), sub-acute hematoma (a lesion equal to the density of the normal brain (isodense) and does not appear in the CT image, but its effects (mass effect) appear, such as: effacement of the cortical sulci, compression of the ventricle, shift of midline structures), and chronic hematoma (a lesion has less density than the normal brain (hypodense)), (Wan Zaki, 2012) Therefore, the aim of this study was to evaluate the physical parameters of brain tissue, particularly the linear attenuation coefficient (LAC) and half-value layer (HVL), using Hounsfield unit (HU) measurements obtained from head CT images of normal and abnormal brain regions.

The study also aimed to assess the differences in these parameters between the two regions and determine their potential usefulness in identifying and characterizing intracranial hemorrhagic lesions. The significance of this study lies in demonstrating how quantitative physical parameters derived from CT images can provide additional information for the assessment of abnormal brain tissue and may support the early detection and characterization of intracranial hemorrhage, particularly when conventional visual interpretation is inconclusive.

## 2. Materials and Methods

**2.1 Materials:** The CT device used generally consists of a gantry and a patient table; the gantry contains X-ray tube, filters, detectors, collimators, etc. All of this is designed in a special room called Scan room, surrounded by walls made of lead to protect from radiation. There is also a control room outside, which contains a computer to control the process of imaging, processing, and outputting images. The CT device used is SOMATOM Emotion 16-slice configuration from SIEMENS, Software Versions (Ag, 2006).

**2.2 Methods:** The scan process is carried out in several steps, as follow:

1. Preparing the patient; the patient lies in the supine position, supports his arms on the body, fixes his head well in the head holder, without any movement. Gantry tilt is available for serial scanning; however, image distortion may occur if spirals are obtained at an angle of inclination greater than (8) degrees. In order to improve image quality compared to radiation dose, scans are provided within a maximum scanning field of 300 mm with iso-center consideration, and it will not be possible to perform any reconstruction task with a field of view beyond these limits. Therefore, patient positioning must be performed accurately to ensure a central position of the skull.

- After preparing and registering the patient, the actual imaging process is carried out in the control room by a computer.
- Storing the resulting image data is stored in the computer and appears on the screen, and the appropriate sections to highlight the locations of the lesion are chosen.
- The appropriate sections of the image are exported to a film or CD, then the resulting images are analyzed by calculating the linear attenuation coefficient and the half-value layer HVL using the Hounsfield numbers obtained from the normal and abnormal areas of the medical image and comparing them, then the conclusion diagnose is found.

### 3. Results and Calculations

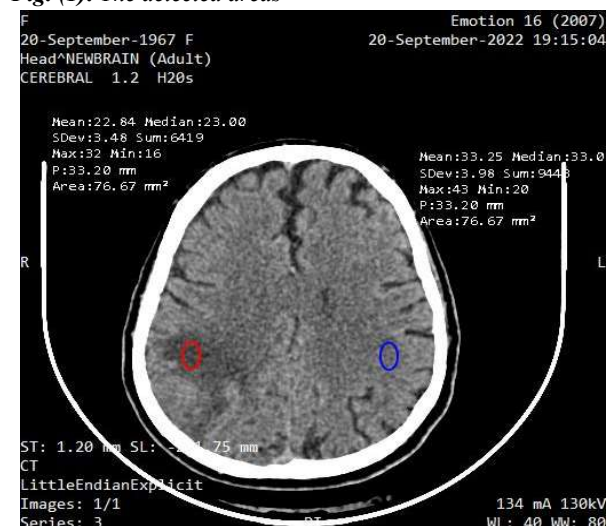
After CT procedures were performed using the head CT protocol for the patient (female, 55 years old) suffering from abnormal brain symptoms, a set of CT images were obtained (See figure 1). Table (1) below shows the values that were used from the brain protocol for this case.

**Table 1**

*Tag Text of the Case*

| Body Part Examined   | HEAD    |
|----------------------|---------|
| KV <sub>p</sub>      | 130 KV  |
| Gantry Detector Tilt | -15°    |
| X Ray Tube Current   | 134 mA  |
| Exposure             | 200 mAs |
| Focal Spots          | 0.95 mm |
| Kernel               | H20s    |
| Window Center        | 40\700  |
| Window Width         | 80\3200 |
| Slice Thickness      | 1.2 mm  |

**Fig. (1): The detected areas**



Mean values of Hounsfield units were obtained (See table 2 below). For the regions marked in figure (1) several calculations were performed according to the following equations:

The linear attenuation coefficient is symbolized by ( $\mu_{\text{tissue}}$ ): Its unit of measurement is ( $\text{cm}^{-1}$ ) based on the following equation:

$$\mu_{\text{tissue}} = \frac{\mu_{\text{water}}[\text{HU}_{\text{tissue}} + 1000]}{1000} \dots (1)$$

When the linear attenuation coefficient of water is equal to:

$$\mu_{\text{water}} = 0.18 \text{ cm}^{-1}$$

Half-Value Layer (HVL): A unit of measurement based on the following equation:

$$\text{HVL}_{\text{tissue}} = \frac{\ln 2}{\mu_{\text{tissue}}} \dots (2)$$

After calculations; the results in table (2) were obtained:

**Table 2**

*Results of the Calculations of Mean Values of Hounsfield Units*

| Mean HU <sub>tissue</sub> |          | $\mu_{\text{tissue}} (\text{cm}^{-1})$ |           | HVL <sub>tissue</sub> (cm) |              |
|---------------------------|----------|----------------------------------------|-----------|----------------------------|--------------|
| Normal                    | Abnormal | Normal                                 | Abnormal  | Normal                     | Abnormal     |
| 33.25                     | 22.84    | 0.185985                               | 0.1841112 | 3.7268983015               | 3.7648289762 |

### 4. Discussion

Initially, the reference HU value for the brain parenchyma in the CT scan of an adult is (less than 40) and its hemorrhagic cells is (less than 80).

From the resulting values in the table (2) obtained based on physical calculations, the following was noticed:

- The average values of Hounsfield units for the areas indicated in the blue circle (normal) were compared to the reference value, while the average value of Hounsfield units obtained in the area indicated by the red circle is very small, which suggests the presence of a defect (abnormal).
- The slight decrease in the (LAC) value and the corresponding increase in the (HVL) value for the (abnormal) area mean a slight decrease in density, which makes it closer to the normal density (iso-dense), which means relatively less attenuation of the X-rays falling on it.
- Considering the location of this area - anatomically - it was noted that it is located in the right posterior parietal-temporal border region, and is supplied with blood by the middle cerebral artery (MCA), which means that the slight difference in density values indicates the presence of a hematoma in this area; we conclude this through some mass effects such as obliteration of some grooves (sulci).
- When all the values were compared with the reference values for the hemorrhagic cells, it was found that these current values for the density of this hematoma are not large and are closer to the intermediate density (Iso dense), which represents sub-acute hematoma and not acute hemorrhage.

### 5. Conclusion

The mean Hounsfield unit (HU) values of the CT images were extracted and analyzed, and the corresponding linear attenuation coefficient (LAC) and half-value layer (HVL)

values were compared. A slight decrease in LAC accompanied by a corresponding increase in HVL was observed in the abnormal region compared with the normal region. Considering these values together with the anatomical location of the lesion, the findings were consistent with an isodense, subacute hematoma. CT is particularly valuable for the rapid assessment of intracranial hemorrhage in emergency settings, whereas MRI provides more detailed information for determining the age of a hemorrhage but is less suitable for rapid emergency assessment. Future studies should include larger patient populations and different stages of intracranial hemorrhage to establish reliable reference ranges for HU, LAC, and HVL. Comparative studies with MRI and clinical diagnoses are also recommended to further evaluate the diagnostic value of these parameters. Standardized imaging protocols and automated quantitative analysis may improve the reliability and clinical applicability of the findings.

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## تحليل المعايير الفيزيائية (HU, LAC &amp; HVL) لنزيف الدماغ باستخدام التصوير المقطعي المحوسب

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## ملخص

تكون الهياكل الداخلية لجسم الإنسان غير مرئية بشكل عام. ومع ذلك يمكن لتقنيات التصوير الطبي المختلفة إنشاء صور تتيح لنا رؤية الجسم من الداخل لتشخيص الحالات غير الطبيعية. ومن تقنيات أمثلة التصوير الطبي التصوير المقطعي المحوسب (CT). في هذا البحث، تم استخدام بروتوكول التصوير المقطعي المحوسب لفحص الرأس لتصوير مريضة تبلغ من العمر 55 عاماً. وقد استخرجت القيم المتوسطة لأرقام التصوير المقطعي، والتي تُسمى بوحدات هاونسفيلد (HU) للصور، ثم حللت من خلال مقارنتها بالمبادئ الفيزيائية لكل من معامل التوهين الخطي (LAC) وطبقة نصف القيمة (HVL). حيث لوحظت انخفاض طفيف نسبياً في قيمة معامل التوهين الخطي، قابله ارتفاع في قيمة وطبقة نصف القيمة في المنطقة غير الطبيعية مقارنة بالمنطقة الطبيعية. وعند مقارنة هذه القيم بالقيم المرجعية للخلايا النزفية لوحظ وجود نزيف حاد ذي كثافة متساوية، وهو ما يسمى وربما دمويًا تحت الحاد.

**الكلمات المفتاحية:** التصوير المقطعي المحوسب، وحدات هاونسفيلد، معامل التوهين الخطي، طبقة نصف القيمة، الكثافة المتساوية.

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