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CLINICAL APPLICATIONS AND TECHNICAL IMAGES OF HOUNSFIELD UNITS IN CT SCAN

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ABSTRACT

This study gives a comprehensive overview of the subject, covering its background, modalities, number of CT scans, Hounsfield units, and scale in relation to specific applications. Currently, computed tomography (CT) has emerged as a groundbreaking technique in the field of medical imaging. In addition to being referred to as the Hounsfield unit, the numerical picture of a pixel is also known as the CT number. The viewpoint that lies behind the quality of the image and the reconstruction of the image in the form of grayscale. The abbreviation for this scale is the HU level. In recognition of Sir Godfrey Newbold Hounsfield, the scale was given the name "Hounsfield Unit." The value of the gray shade is represented by this scale according to the attenuation. Because it assists in determining the degree of radiation intensity decrease and, as a result, provides a specific numerical value in each pixel, attenuation plays a significant part in the process. Information on the HU value may be obtained by establishing a region of interest (ROI) on a specific slice or segment of an image. This information is helpful in determining the relevance of the HU value in terms of detection, assessment, therapy, and diagnosis. The return on investment (ROI), which is taken into consideration and utilized in post-processing approach, provides HU value immediately following its placement, which is not less than Artificial Intelligence (AI).

Keywords : *Attenuation , HU scale , Hounsfield Unit , Region of Interest (ROI)*

INTRODUCTION

The practice of radiology has been completely transformed as a result of the development of the CT scanner. When compared to the diagnostic information obtained through conventional x-ray techniques, computed tomography (CT) is particularly remarkable because it generates a significant increase in diagnostic information in many instances. The extraordinary innovation was made possible by the efforts of a number of people, the most notable of whom were Godfrey Newbold Hounsfield and Allan Macleod Cormack.

EARLY EXPERIMENTS

In the beginning of his studies, when Hounsfield was developing the CT scanner, he employed heterogeneously enhancing with a homogeneous beam, which means that all of the photons had the same amount of energy. This was due to the fact that such a beam satisfies the requirements of the lambert-beer law, which is an exponential relationship that describes what happens to the photons as they travel through the tissues. Because there are two different kinds of radiation beams—homogenous and heterogenous—this was a cause for concern over the situation.

The objective is to determine the linear attenuation coefficient, which quantifies the extent of attenuation (decrease in the intensity of radiation as it travels an object). Thus, it is a numerical measurement expressed in centimeters, thus the word "linear."

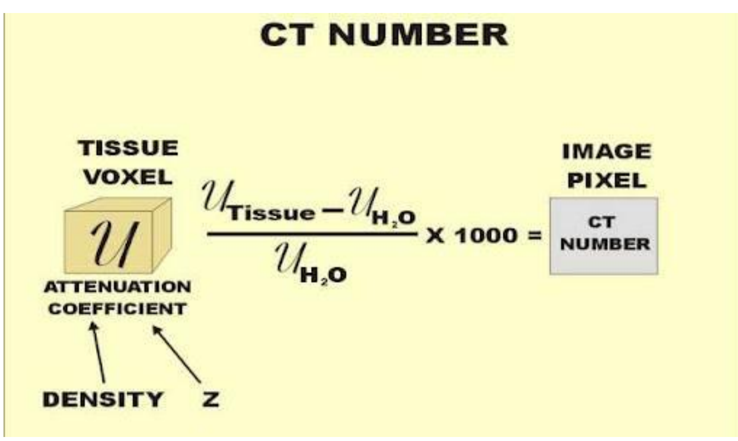
GODFREY NEWBOLD NEWBOLD HOUNSFIELD: PERSPECTIVES ON HISTORY

In the year 1919, Godfrey Newbold Hounsfield was born in the county of Nottinghamshire for the United Kingdom. He received his education in mechanical, electrical, and electronic engineering. In 1967, Hounsfield was conducting research on the use of computers to investigate various strategies for pattern recognition and reconstruction. As a result of this investigation, he came to the conclusion that it would be possible to get information about the interior structures of a body by passing an x-ray beam through an item from all directions and then measuring the amount of x-ray transmission that occurred.

Under the guidance of Dr. Ambrose, the first clinical prototype CT brain scanner, known as the EMI Mark 1, was placed in the hospital that was run by Atkinson-Morley in 1971. Clinical research were also carried out during this time. The very first patient to be scanned by this system was in the year 1972. The research conducted by Dr. Hounsfield led to the creation of a CT scanner that is therapeutically helpful for imaging the brain. Hounsfield was awarded the MC Robert award for his contributions in this field. Dr. Hounsfield laid the groundwork for a new field of study for technologists, radiologists, medical physicists, engineers, and other scientists who are associated with the field of medicine by constructing the first operational CT scanner.

CT NUMBERS

A CT scanner produces a digital representation of the image it produces. The structure is made up of a square matrix of pixels, which are the image element. Each pixel represents a voxel, which is the volume element, of the inner structure of the item, which is the patient. When determining the size of the voxel, the matrix size, the field of view (FOV) that is chosen, and the section thickness are all taken into consideration. When the attenuation values of the scanned tissues are normalized to those of water, CT numbers are defined as the result obtained.



Radiologists often see cortical thickness readings as absolute measurements that can be definitively attributed to organs. Deviation of CT readings for certain organs indicates the presence of disease. Numbers obtained from CT scans are quantitative and can be utilized for clinical diagnostic purposes, including lung nodule, degrees of calcification, bone density, fracture risk, and tumor volume or lesion diameter calculations. CT numbers are assigned to each every pixel that makes up the reconstructed image. Calculating the CTnumber, which may be reproduced as a numerical image, is the responsibility of the computer. Because a grayscale image is more beneficial to radiologist than a numerical output, this image has to be turned into a grayscale image. A brightness level that correlates with the CT number is provided for the purpose of making this conversion easier.

$$\text{CT number} = \frac{(\mu_t - \mu_w)}{\mu_w} \cdot k$$

where ,k = constant / contrast factor

$(\mu_t$ μ_w & are the linear attenuation coefficients, as the CT, x-ray energy of the tissue within the pixel & water respectively

Hounsfield Units are a different term for CT numbers, which are used when k = 1000. In remembrance of Godfrey Newbold Hounsfield, the numerals assigned to Connecticut are often referred to as Hounsfield Units. Hounsfield Units are a dimensionless unit that is extensively utilized in CT scanning for the purpose of expressing cortical thickness measurements in a format that is both consistent and easy.

HOUNSFIELD UNIT (HU) SCALE: AN IMPORTANT ASPECT

According to medical CT, the HU scale is a quantitative scale that is used to describe radiodensity. It also offers an exact density for the kind of tissue being examined. The H-scale is able to express the symbol 'μ' with more precision due to the fact that the contrast scale is 0.1% per CT numbers. In order to determine CT numbers, a relative basis is utilized, with the attenuation serving as a reference base. For the purpose of producing grayscale imaging during CT reconstruction, the absorption attenuation coefficient of radiation within a tissue is utilized. There is a direct correlation between the absorption attenuation of the x-ray beam and the volume of tissue that is physically dense. Positive values are associated with more dense tissue that has a larger x-ray beam absorption, and this tissue looks bright. Conversely, less dense tissue that has a lower x-ray absorption has negative values and appears dark.

The linear transformation generates a Hounsfield Unit (HU) scale that is seen as shades of gray.

SUBSTANCE	HU RANGE
AIR	-1000
FAT	-120 TO -90
SOFT TISSUE ON CONTRAST CT	+100 TO +300
CORTICAL BONE	+1800 TO +1900
BLOOD	+40 TO +60
WATER	0
BILE	-5 TO +15
URINE	-5 TO +15
CHYLE	-30
CEREBROSPINAL FLUID	+15
LUNG	-700 TO -800
KIDNEY	+20 TO +45
LIVER	60+/-6
MUSCLE	+35 TO +55

APPLICATIONS OF HOUNSFIELD UNIT

1. **QUANTIFICATION OF PULMONARY EDEMA** : It is essential to quantify pulmonary edema and congestion in order to provide direction for diagnostic procedures, to stratify patients based on their risk, and to objectively assess new treatments for heart failure. It is possible to represent CT density in a standardized manner by utilizing Hounsfield, and the density may be quantified by using the linear transform of the attenuation coefficient that has been measured. On the human unit scale, the range of values is as follows: -1000 for air, 0 for water, 2000 for bone, and 3000 for metal.The majority of the voxels found within the lung have HU values ranging from -1000 to 0, with a decreasing frequency of negative numbers as the amount of water present increases. HU values inside the region of interest (ROI) varied from -720 to -620 in patients with pulmonary edema and from -950 to -650 in individuals without pulmonary edema. Large arteries, the heart, and the trachea were excluded from the estimation of HU values.

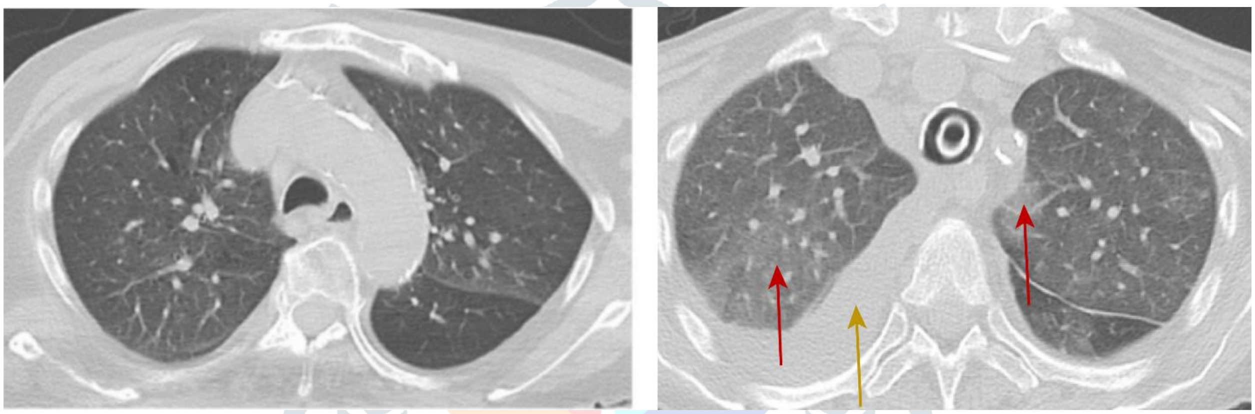


Figure 1 : The left image shows no overt signs of pulmonary edema. Extravascular lung water can be calculated based on HU within ROIs not including identifiable vessels as (HU= + 1000)/10.The right image demonstrates ground glass opacification (red arrows), which has been used in a visual scoring based on its extent and homogeneity .

Note : Apical septal thickening, right pleural effusion (yellow arrow), and minor thickening of the left oblique fissure, all pointing toward increased lung water.

2. **ASSESSMENT & TREATMENT OF URINARY STONES :** Examining stones in the urinary system is a common application of computed tomography (CT). The density of the stone in the kidney is another factor that may be evaluated by CT, in addition to the site and position of the stone and the general health of the kidney. The density of the tissue or stone is connected to the Hounsfield density, which is assessed by CT. There is a correlation between the two. HUs have been utilized in the diagnostic process to provide predictions regarding the kind and opacity of stones.

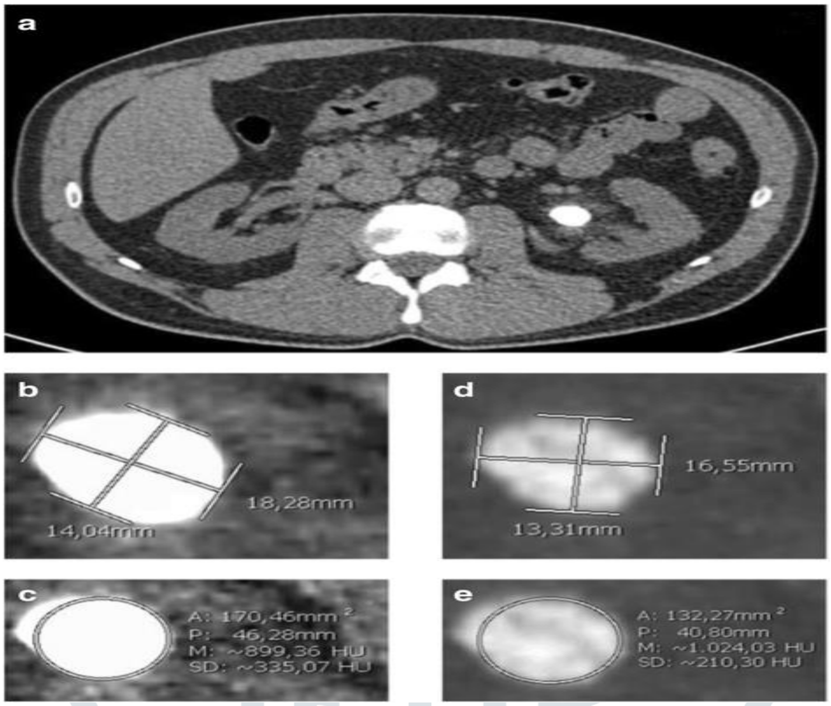


Figure 2 : Shows ROI placement and measurement of renal calculi

The density of the stone or structure of interest is connected to the utilization of HU, which is a parameter that is created from conventional CT.

	HU	REMARKS
	Density less than 76/mm	Non-calcium stone
PREDICTION OF STONES	Mean,879 +/- 230	Calcium oxalate monohydrate stone
	Mean, 844 +/- 346	Apatite stone
	Mean , 550 +/- 74	Cystine stone
	Less than 500	Uric acid stone

3. MEASURING ATTENUATION TO DETECT ABNORMALITIES:

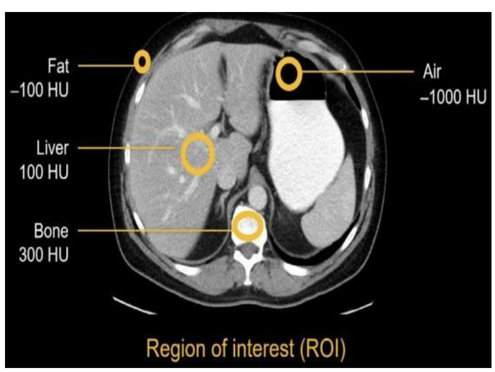


Figure 3 : Showing HU values of different region with the help of ROI

A structure's density is what affects how well it prevents x-rays from reaching the detector, which in turn defines how it appears on a computed tomography (CT) scan. Because they do not block as many x rays, structures that are dense, such as bone or contrast, look brighter. On the other hand, structures that are not dense, such as air and fat, appear darker, even black, because they do not block as many x-rays.

EXAMPLE 1: ASCITES

In CT scan, There is an accumulation of a simple fluid in the abdomen, which is also known as ascites, which is usually linked with cirrhotic liver disease. Due to the fact that the pelvic fluid measures 10 HU, we may deduce that this accumulation is occurring.

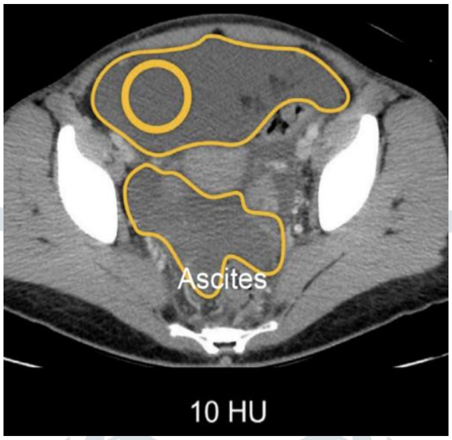


Figure 4: Circular region showing ascites

EXAMPLE 2 : OVARIAN MASS

An example of an ovarian mass may be seen in the image below.Attenuation is measured to be -100 HU when a circular region of interest (ROI) is drawn across the darkest section of the mass. This result is compatible with fat because it is consistent with the presence of fat. With this information, we are better able to make an accurate diagnosis of a benign fat-containing tumor of the ovary that represents a mature teratoma.

Figure 5: Mature Teratoma

EXAMPLE 3: CONTRAST ENHANCEMENT

Following is an image that illustrates the change of the hu value in the renal mass following the uptake of contrast in the CT scan. This transition indicates that there is greater attenuation due to the radio opacity of the contrast, which represents an anomaly when further assessment is performed.

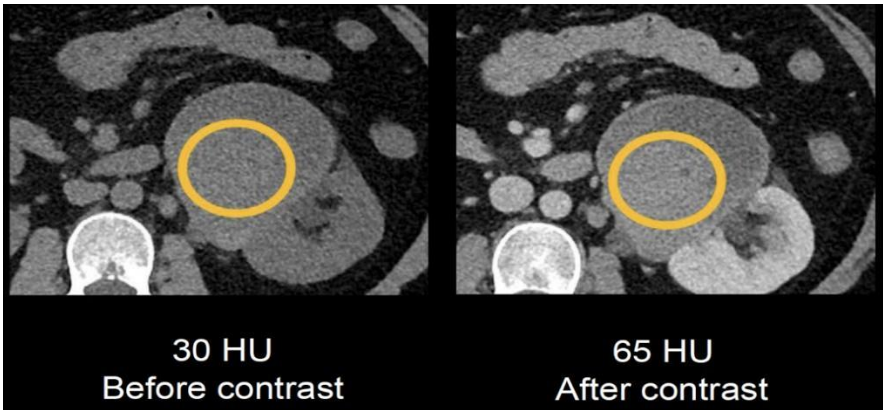


Figure 6: Change in HU Values - PRE & POST CONTRAST

CONCLUSION:

The paper concludes that the foundation of CT image generation and quality is CT numbers, also known as Hounsfield units. When it comes to distinguishing between two tissues that are closely linked to one another, all of the various gray shades, in addition to the black and white idea that is explicitly described in the HU scale, show to be crucial. When it comes to assisting with diagnosis and incorporating its idea into a variety of therapeutic applications, HU has shown to be of great use.

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