Medical Science

Scientific Journal of University of Benghazi

SJUOB (2025) 38 (1) Medical Sciences: Alfadeel, 193 – 214
www.sjuob.uob.edu.ly

Impact of CT Stroke Window Settings on Acute Stroke Detection.

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Received: 15 / 01 / 2025 | Accepted: 24 / 05 / 2025 | Publishing: 29/06/2025

ABSTRACT

Non-contrast CT is the most important imaging modality in the evaluation of suspected acute stroke by excluding intracranial haemorrhage and directly visualizing early ischemic changes. These changes are challenging to detect on non-contrast CT due to the small reduction in the attenuation value of ischemic tissue from normal. The study's objective was to assess the use of stroke window settings for improving the detection of acute stroke. This retrospective study included forty-nine patients in whom non-contrast CT were performed for suspected acute stroke within 24 hours from symptom onset. Images were reviewed in two reading sessions with different window settings used: default brain window (80/40 [window width/window level]) and stroke window (40/40 [window width/window level]). Both windows were evaluated for their ability to detect early ischemic changes with the final diagnosis as the reference standard. Twenty-nine patients had a final diagnosis of acute stroke. The sensitivity and specificity of non-contrast CT for acute stroke detection were 79.3% and 100% respectively at the default brain window. Both windows were comparable for detecting acute stroke (P=0.2). The CT sensitivity increased to 86.2% after adding the stroke window review to the default brain window. The resultant improvement in CT diagnostic performance by stroke window review was not statistically significant (P=0.5). Conclusion, the superior sensitivity of applying stroke window settings after the default window review is small with modern generation CT scanner. These findings should increase the confidence in routine radiology reporting that uses the standard brain window in the assessment of acute stroke.

Keywords: Default brain window, Early ischemic changes, Non-contrast CT, Sensitivity, Stroke window, Window settings, Window width.

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 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018

1.INTRODUCTION

Stroke is one of the most common causes of death and disability in the world. Stroke deaths in Libya reached an estimated 10% of total deaths, according to the latest WHO data published in 2020 [1]. Early non-contrast computed tomography (CT) is the most important modality in the evaluation of suspected acute stroke. It helps exclude haemorrhage and other alternative diagnoses such as neoplasms and aids in establishing the specific diagnosis of acute ischemic infarct, precluding the need in most cases for any additional imaging once the diagnosis of stroke is made [2]. Despite the higher sensitivity of magnetic resonance imaging (MRI) in detecting early ischemic changes, CT scan remains the preferred imaging tool in assessing acute stroke, as CT is faster, relatively lower in cost, and widely available [3, 4].

The interpreting of CT images utilizes the Hounsfield unit (HU), also called CT unit, a relative quantitative measurement of radio-density. During CT reconstruction, a grayscale image is created using the radiation's absorption/attenuation coefficient within a tissue, which is directly proportional to the physical density of the tissue. The denser the tissue, the more the X-rays are absorbed, and the higher the number of HU [5, 6]. On the Hounsfield scale that appears as grey tones, the greater X-ray beam absorption in more dense tissue results in positive HU values and a brighter appearance, less dense tissue, on the other hand, has negative HU values and a darker appearance [5]. Water is defined as having a Hounsfield Unit of zero and air as having -1000. For dense bones, the upper limits can be as high as 1000; for metals like steel or silver, they can be as high as 3000. Muscle, about 40 HU; fat, −60 HU; grey matter, 40 HU; white matter, 30 HU; cerebrospinal fluid, 10 HU [5, 7]. In order to visualize sufficient contrast resolution on a workstation monitor and maximize the contrast resolution of structures with similar attenuation values, the interpreting radiologist must examine the CT data in multiple linear window settings, usually optimized for soft tissue, lung, and bone [8]. Windowing is the process of changing window settings to adjust the grayscale range of a particular image to better visualize particular structures. Window settings are comprised of window width (WW), the range of CT units, i.e. the greyscale displaced in an image, and window

 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018

level (WL), the centre value of this range [9]. Only tissues with HU values inside the selected window width are translated onto the grayscale spectrum; tissues with HU values outside of the window width are configured to be either all black or all white [6]. WW controls the contrast of the image. Decreasing window width increases the contrast resolution of structures with similar HU values, as a smaller change in attenuation value is given a different shade of grey, while increasing the window width decreases the contrast as a larger difference in HU values is needed to change the tone of grey allocated to certain HU. Decreasing the window level increases the brightness of the image as lower HU values are needed to be displayed on the brighter side of the greyscale [9].

Adjusting window settings (WW/WL) are frequently used to highlight certain areas and details. As default, different window settings are assigned to different anatomical regions for examination so that areas of interest can be easily identified [10]. For evaluation of brain abnormalities, an appropriate centre level setting and a tiny window width significantly increase the ability to identify lesions. Brain CT images are typically reviewed in the default brain window settings of WW 80 HU and WL 40 HU [11].

Subtle differences in HU from normal may go undetected on default window settings. The fundamental concept is that in order to detect subtle abnormalities, radiologists should try to accentuate contrast between normal and abnormal tissues by choosing a narrower CT window width [12]. Early CT findings in acute stroke are challenging to detect due to small reductions in the attenuation of ischemic tissue from normal [11]. There have been various approaches to the use of variable window settings to improve acute stroke detection from CT images [10]. Using a stroke window (40/40 [WW/WL]) settings could improve brain lesion detection [13]. Although the literature advocates for stroke window settings, their diagnostic value with modern CT scanners remains unquantified. To my knowledge, despite discussion in the literature about the importance of narrowing window width in the detection of acute stroke, the benefit of stroke window settings in enhancing the diagnosis of acute stroke with modern multidetector and dual-source scanners has not been stressed. The aim of this study is to assess the use of stroke window (40/40 [WW/WL]) settings in enhancing the detection of acute stroke.

2.METHODS

This is a retrospective study aimed at patients admitted at Albeida Medical Centre and referred for imaging at the CT unit of Omer Almukhtar General Hospital with suspected acute stroke diagnosis over the period from December 2020 to November 2021.

2.1.Subjects

The CT brain scan studies done consecutively over the 12-month period were retrospectively retrieved from the picture archive and communication system (PACS) of CharruaSoft (Version 6.31.0). A total of three hundred and twenty-three of patients aged ≥ 20 years with a single non-contrast CT brain study were included in the image review process. The hospital records within the same period of these patients' scans were then reviewed. Patients who were not referred from the hospital's medical department were excluded. The inclusion criteria for the remaining patients were as follows: (1) patients who had been admitted with sudden onset of neurological deficits suggesting acute stroke, such as hemiplegia and aphasia. (2) Patients who had undergone non-contrast CT imaging within 24 hours from onset of symptoms. Forty-nine patients were eligible for inclusion with suspected acute stroke and non-contrast CT brain scans within 24 hours after symptom onset.

The 49 patients were 34 to 85 years old with a mean age of 62.8 ± 13.5 years (± stands for standard deviation (SD)). Twenty-six were men and twenty-three were women. The relevant data to the purpose of the study, like clinical history, physical examination, imaging findings, and the final diagnosis at the end of the hospital stay, were recorded from patients' medical records. The final diagnosis served as the reference standard for CT stroke detection performance at different window settings.

2.2.CT image acquisition

The non- contrast CT scans were performed with a 32 slice CT scanner (Aquilion, Canon Medical Systems, Japan) using the scanning technique of 120 kV, 180 mA, 0.8 second rotation time, and 5 mm section thickness. Contiguous axial slices were produced parallel to the inferior orbitomeatal line, covering from skull base to vertex. All images were reconstructed in 5-mm thickness with a 3-mm reconstruction interval for

 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018

averaged and MIP images from 1 mm thickness non-contrast axial source images using the CT scanner console.

2.3.Image analysis

A single radiologist assessed the brain scans. All CT images were reviewed with the radiologist being blind to patient clinical information except patient' name, age, and sex, which were available in the DICOM reviewer by default. The non-contrast CT images were viewed in two reading sessions with different window settings used. The first readout of CT images was done at the default brain window (WW/WL [80/40]). Four weeks later, and in a different order from the first reading session, the images were viewed at the stroke window set to WW 40 HU and WL 40 HU. During each reading session, the images were thoroughly assessed for early signs of stroke. These were identified as follows:

- Loss of grey-white matter differentiation. It includes the loss of grey-white matter distinction at the insular cortex, the basal ganglia, and the cortical gyri (Figure 1a).

- Parenchymal hypoattenuation, defined as a region of cortical-subcortical or parenchymal decreased attenuation within a vascular territory relative to the attenuation of other parts on the same side or of the contralateral hemisphere, with or without focal brain swelling in form of sulcal effacement or ventricular compression (Figure 1b).

- Hyperdense artery sign, identified as increased attenuation of an artery compared to the contralateral artery due to the presence of an intrarterial clot. It can be seen at M1 and M2 segments of the middle cerebral artery (MCA), A1 and A2 segments of the anterior cerebral artery (ACA), the intracranial internal carotid (ICA), the basilar, and the vertebral arteries (Figure 1c).

In addition to the early ischemic changes of stroke, the CT images were also routinely evaluated for alternative diagnoses such as haemorrhage, infection, and intracranial masses that may mimic acute stroke presentation.

In cases of MCA territory infarct, the location and the extent of hypoattenuation on CT were classified according to the Alberta Stroke Program Early CT Score (ASPECTS). The MCA territory was divided into 10 regions: caudate nucleus, internal capsule, lentiform nucleus, insula, and six cortical regions (M1-M6) at ganglionic and supragan-

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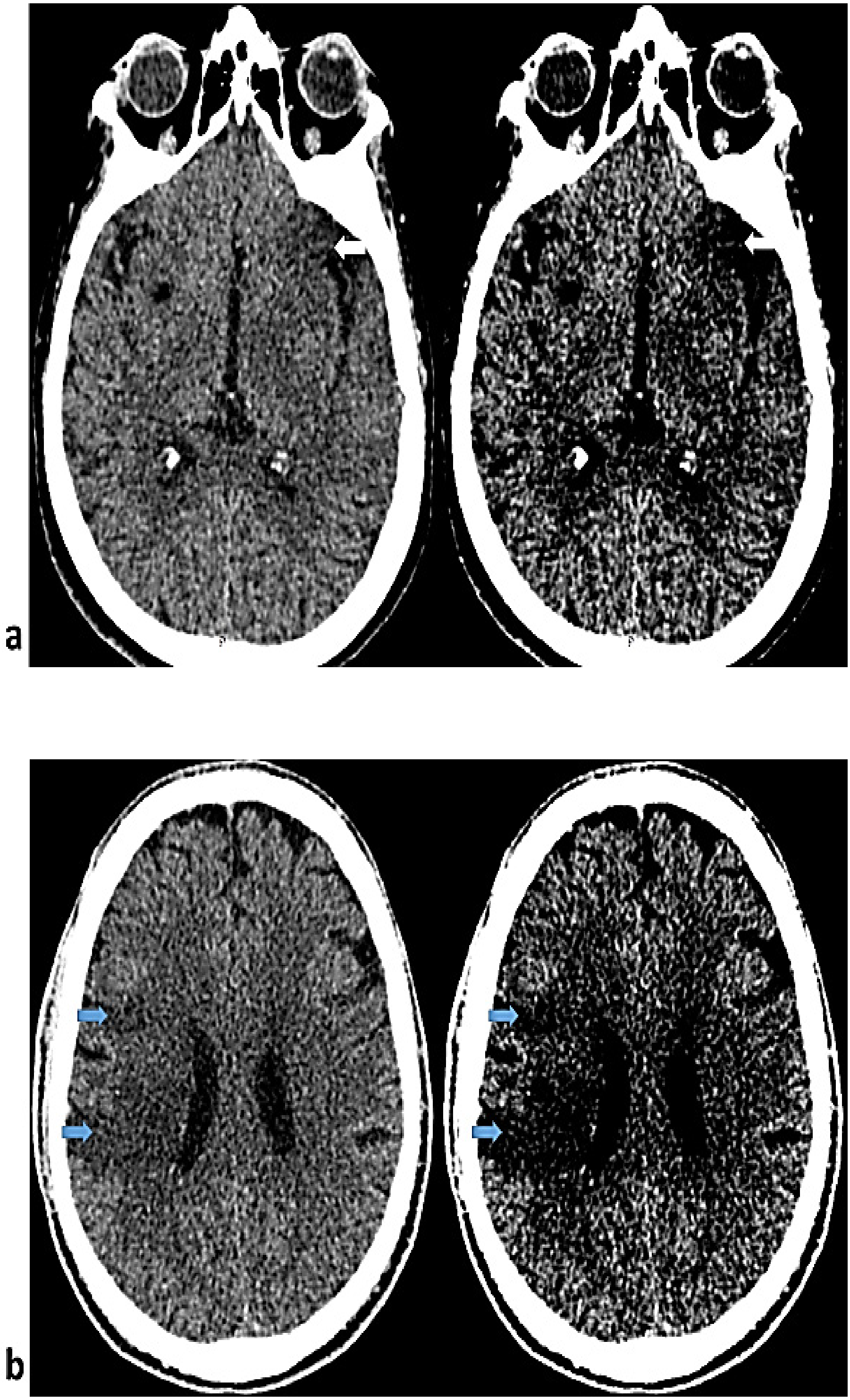
glionic levels. A score of 10 points indicates no ischemia (normal). One point is deducted from that score for each region showing early ischemic changes (parenchymal hypoattenuation, or loss of corticomedullary differentiation).

2.4.Statistical analysis

For diagnostic assessment, sensitivities and specificities with 95% confidence intervals (CI) were calculated for detecting acute stroke by viewing images at default brain window and stroke window settings using the final diagnosis as the reference standard. In addition, a receiver operating characteristic (ROC) curve was generated to assess the diagnostic performance of both window settings. Area under the curve (AUC) of the respective ROC curve indicates the diagnostic accuracy of the window settings. The areas under the ROC curves for the default brain window and stroke window were compared to detect the difference in the diagnostic accuracy between the two windows. The diagnostic performance of combined image viewing of both window settings was evaluated using McNemar's test. For comparison of the detection rate of early ischemic signs on the two windows, Fisher's exact test was applied. A paired samples t test was used to illustrate the differences in ASPECTS scores between the default brain window and the stroke window in patients with MCA territory infarcts. All statistical analyses were performed by using MedCalc software version 20.027 (MedCalc Software by Ostend, Belgium, https://www.medcalc.org). A p value of < 0.05 indicated statistical significance.

 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018



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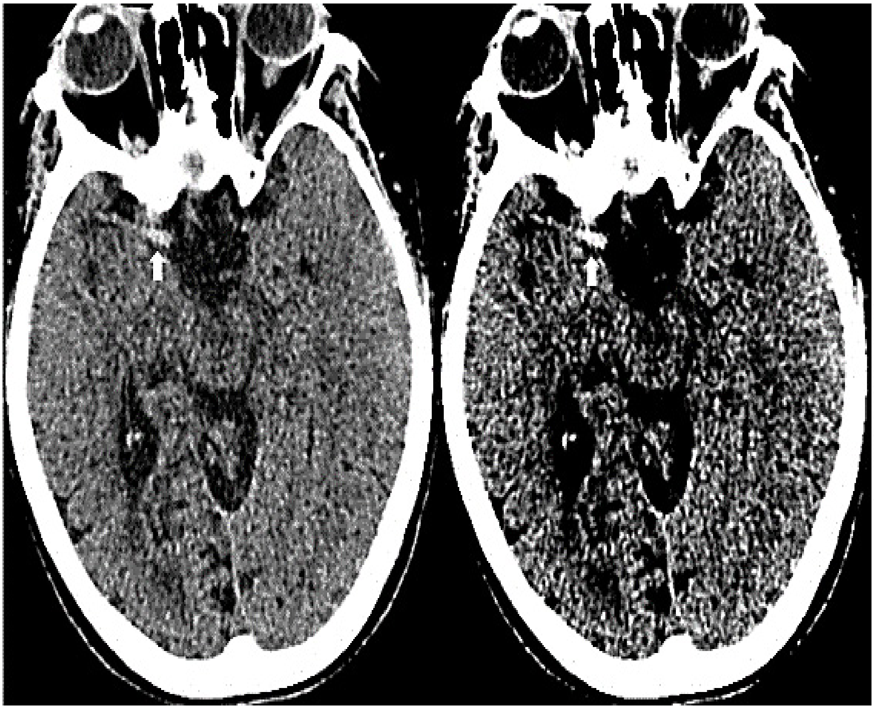

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Figure .(1). Illustrates early ischemic changes on noncontract CT of different patients. (a)- Grey-white matter differentiation loss seen at anterior part of left insula (white arrow). (b)- Parenchymal hypoattenuation (blue arrows). (c)- Hyperdense artery sign involving the M1 segment of the right MCA (white arrow).

3.RESULTS

Of the 49 patients, 29 patients (59%) had a final diagnosis of acute stroke, while eight patients suffered from transient ischemic attacks (TIA) and six patients had intracerebral haemorrhage. The final diagnosis of all patients is shown in Table 1

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Table .(1): Final diagnosis of the 49 patients with suspected acute stroke.

Diagnosis	No of patients
Acute stroke	29
TIA	9
Intracerebral haemorrhage	7
Cerebritis/encephalitis	2
Space occupying lesion	1
Subarachnoid haemorrhage	1

The mean age of the 29 patients with acute stroke was 63 years ± 13 (SD) with a range of 34 to 85 years. Sixteen of them were women, and thirteen were men. Based on clinical and CT findings, 20 patients had MCA/ICA territory stroke, two patients had ACA territory infarct, two patients had posterior cerebral artery (PCA) territory infarct, one patient had basilar artery territory stroke, three patients had posterior inferior cerebellar artery (PICA) territory infarcts and one patients had superior cerebellar artery (SCA) territory infarct.

The sensitivities and specificities of non-contrast CT for the detection of acute stroke at different window settings are detailed in Table 2. The sensitivity and specificity of CT for stroke detection at default brain window settings were 79.3% (95% CI: 60.2-92) and 100% (95% CI: 83.2-100) respectively. The corresponding sensitivity and specificity at stroke window settings were 72.4% (95% CI: 52.8-87.3) and 95% (95% CI: 75.1-99.8) respectively. In one case, the parenchymal hypoattenuation due to chronic infarct was falsely interpreted as a new infarct during the stroke window reading session resulting in the reduction of the specificity to 95% for the stroke window review. The stroke window settings improved stroke detection in only two cases where grey-white matter differentiation loss and hyperdense artery sign were missed at the default brain window reading session but subsequently de-

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National Library of Libya, Legal number: 154/2018

tected at the stroke window reading session (Figure 2). On the other hand, early ischemic changes were missed at the stroke window reading session in four cases (three parenchymal hypoattenuation, one grey-white matter differentiation loss) that were previously detected at the default brain window. The sensitivity and specificity for stroke detection when findings from image review at the default brain window and the stroke window were combined (i.e., true positives and true negatives at one or both reading sessions) were 86.2% (95% CI: 68.3-96.1) and 100% (95% CI: 83.2-100) respectively. There was no statistically significant diagnosis performance improvement in acute stroke detection when readings at the default brain window and stroke window were combined (McNemar test, P=0.5).

The ROC curves for stroke detection at the default brain window and stroke window are shown in Figure 3. The analysis of ROC curves showed high diagnostic accuracy of non-contrast CT for detecting acute stroke within 24 hours at both the default brain window (AUC=0.891, P<0.001) and stroke window settings (AUC=0.821, P<0.001). By comparing areas under the ROC curves, there was no statistically significant difference in the accuracy of stroke detection between default brain window and stroke window settings (P=0.2); see Figure 4. Early ischemic changes were identified at both windows in 25 (86.2%) of the 29 patients with acute stroke. parenchymal hypoattenuation was detected in 21 cases (72.4%), grey-white matter differentiation loss in 10 cases (34.5%), and hyperdense artery sign in six cases (20.7%). Numbers of individual early ischemic changes that were detected on different window settings are detailed in Table3. There was a difference in the rate of detection of parenchymal hypoattenuation between the default brain window and the stroke window settings. However, the difference did not reach statistical significance.

In the 20 patients with MCA territory infarcts, the difference in the mean of ASPECTS scores between the default brain window and the stroke window was not statistically significant (P=0.6).

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Table .(2): Sensitivities and specificities of CT for acute stroke detection at different window settings

Window settings	Final diagnosis		Sensitivity (TP/TP+FN)	Specificity (TN/TN+FP)
	Acute stroke (n=29)	No acute stroke (n=20)		
Default brain window (80WW/40WL)				
EIC present	23 (TP)	0 (FP)	79.3 (23/29)	100 (20/20)
EIC absent	6 (FN)	20 (TN)		
Stroke window (40WW/40WL)				
EIC present	21 (TP)	1 (FP)	72.4 (21/29)	95 (19/20)
EIC absent	8 (FN)	19 (TN)		
Combined (default brain and stroke windows)				
EIC present	25 (TP)	0 (FP)	86.2 (25/29)	100 (20/20)
EIC absent	4 (FN)	20 (TN)		

WW= window width, WL= window level, EIC= early ischemic changes, TP= true positive, FN= false negative, TN= true negative, FP= false positive.

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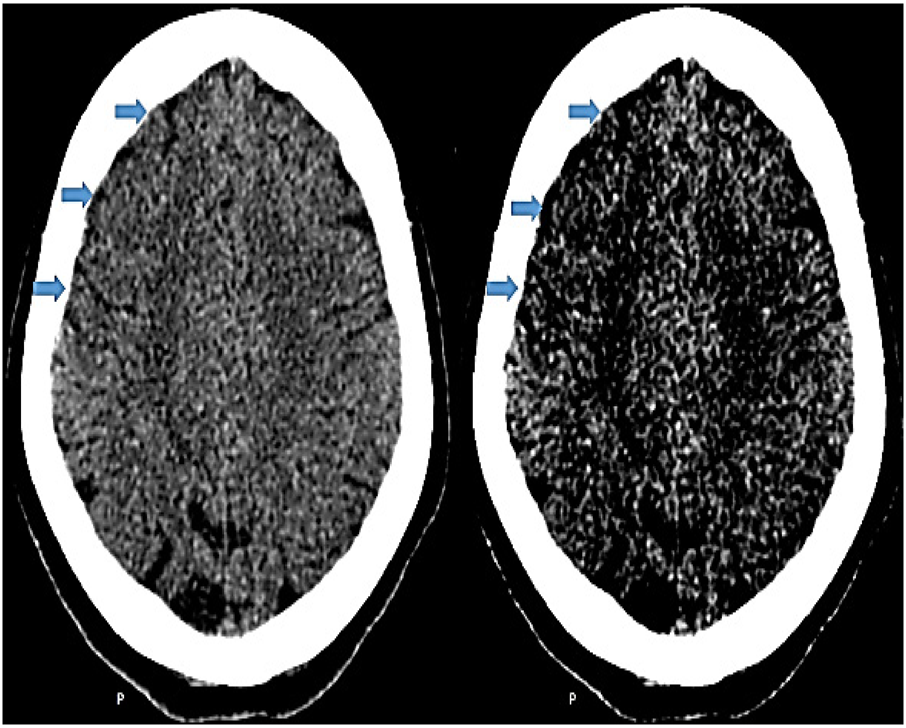

Figure .(2). Non-contrast CT brain of a patient with an acute right MCA stroke.

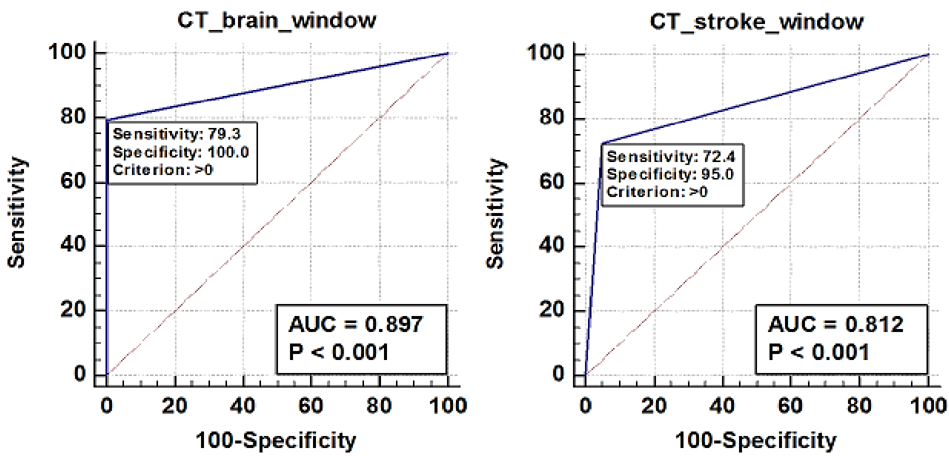

Figure .(3). ROC curves for stroke detection at default brain window and stroke window settings.

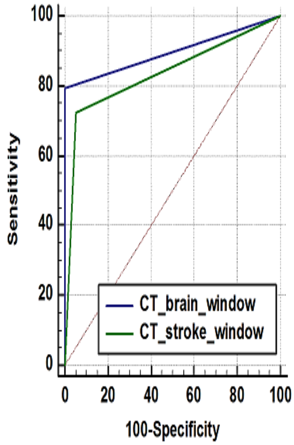

Figure .(4). Comparison of the ROC curves for stroke detection at default brain window and stroke window settings.

Table .(3): Comparison of the number of individuals early ischemic changes detected at default brain and stroke window settings.

EIC	Number of EIC detected at default brain window	Number of EIC detected at stroke window	P value
Parenchymal hypoattenuation	21 (72.4%)	18 (65.5%)	0.6
Grey-white matter differentiation loss	9 (31%)	9 (31%)	1
Hyperdense artery sign	5 (17.3%)	6 (20.7%)	1

The data are expressed as number and (percentage). EIC (early ischemic changes).

4.DISCUSSION

Early identification of a clinically suspected stroke on CT imaging is important in conditions where therapeutic treatment is considered. Authors have raised interest in using different window settings as a way of increasing the visualization of early ischemic changes on non-contrast CT. They reported that narrowing window width and window level might increase the sensitivity of stroke detection [14, 15]. Turner et al. [13] suggested that stroke window settings of 40 WW/40 WL should be used routinely in radiological evaluation of all non-contrast CT brain examinations and not just in cases of suspected stroke; his justification is that the reduced window width would increase the image contrast and subsequently increase the conspicuity of subtle abnormalities. However, the sensitivity of the stroke window (40/40 [WW/WL]) for acute stroke detection has not been documented. This study investigated whether the stroke window settings would increase acute stroke detection by modern generation CT scanners. The present study reveals that default brain and stroke windows are comparable for detecting signs of acute stroke with no significant difference when the images are of good quality obtained by multislice helical scanners.

Non-contrast CT remains the first-line imaging tool for patients who present with signs and symptoms suggestive of acute stroke due to its advantages of availability, easy accessibility, speed, convenience to both patient and staff, and high sensitivity for detecting hemorrhage [16]. Acute stroke can be identified on CT by evaluating the images for early ischemic changes. One of the early ischemic changes of stroke seen on CT is the hyperdense artery sign reflecting clot formation within the vessel. Clots that are rich in red blood cells have higher CT attenuation than normal blood and appear hyperdense on CT [17]. Oguro et al. [18] reported a hyperdense MCA sign's sensitivity of up to 57%. After the reduction in cerebral blood flow due to arterial occlusion, the attenuation of grey matter, which has higher attenuation than the white matter due to its large blood volume, decreases and becomes similar to the adjacent white matter. The Loss of grey white matter differentiation can be visible early post stroke onset particularly in areas that has poor collateral supply namely the basal ganglia and insular cortex [17]. Parenchymal hypoat-

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tenuation correlate to increased water content of the affected tissue within the first hours after onset of ischemia caused by the disruption of blood-brain barrier [2, 19]. The ischemia causes failure of membrane ion bombs leading to cytotoxic oedema within 30 minutes from onset of ischemia, accumulation of water within tissues occurs within few hours [20]. The increased water content decreases the CT attenuation of the involved area; an increase by 1% of water content causes 2.5 HU reduction [14]. The parenchymal hypoattenuation is subtle and difficult to detect in the first few hours since onset, it becomes visible to the human eye when the affected brain tissue has underwent significant uptake in water to change HU [17].

The ability of the observer to detect early ischemic changes on non-contrast CT is dependent on various factors, including the size of the infarct, the vascular territory of the infarct, the timing of the scan from the onset of stroke, the generation of the scanner, and the specific methods employed. The expertise of the CT reader and the availability of appropriate clinical information at the time of review also affect the detection of early ischemic changes [20, 21]. Previous studies have shown limited sensitivity of non-contrast CT in posterior fossa infarcts, lacunar infarcts, and hyperacute stroke detection [22]. The advancements in multidetector CT with rapidly improving hardware and software have improved detection of early ischemic changes on non-contrast CT. The reason for the higher detection rate of these early ischemic signs is the enhanced contrast and spatial resolution of the scanner, increasing the ability to visualize subtle reduction in the CT attenuation (HU) of the affected brain [2]. Using readers that are more experienced is another way to maximize acute stroke detection by CT. Numerous studies reveal that residents, neurologists, and acute care doctors read CT scans very differently, although neuroradiologists interpret them less differently. However, in daily practice, neuroradiologists are not always engaged in the work-up for acute stroke. On the other hand, there is evidence that even brief training may improve the ability of non-specialists to identify strokes [20].

The diagnostic sensitivity of CT for acute stroke detection is widely variable in previous reports. Authors using early generation CT scanners from the early 1980s have reported poor sensitivity of non-contrast CT

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for the detection of early signs of stroke, with sensitivity as low as 10% within 48 hours from symptom onset. However, with current CT scanners, early ischemic changes can be seen as early as three hours [20]. In one report, the sensitivity of non-contrast CT for hyperacute stroke in the first three hours was 26% [23]. The sensitivity of non-contrast CT can reach up to 82% within 6 hours of symptom onset [22]. The specificity for acute stroke detection on non-contrast CT was 100% [24]. In the current study, the results were comparable with previous reports in the literature. Non-contrast CT showed 79% sensitivity for acute stroke detection within 24 hours from symptom onset, and the specificity was 100%.

CT sensitivity for stroke detection in the present study increased from 79% to 86% but not significantly (P=0.5) after stroke window settings (40/40 [WW/WL]) were added to the default brain window (80/40 [WW/WL]) review. Previous studies have shown that the use of narrow window settings increases the conspicuity of early ischemic changes on non-contrast CT. However, no author had investigated stroke window settings of 40/40 (WW/WL) before this study, even though many in the literature advocated the application of these window parameters in the evaluation of acute stroke patients. Lev et al. [14] in 1999 did the first study that compared a standard brain window to variable window settings. They retrospectively reviewed 21 patients with proved MCA infarction who had undergone non-contrast CT imaging within 6 hours of stroke onset. The readers costume adjusted as necessary two preset values of 8 WW with 32 WL and 30 WW with 35 WL (range; 1-30 WW, 28-36 WL) to the standard window settings preset to 80 WW and 20 WL. The sensitivity for stroke detection was 57% at standard window settings and significantly increased to 71% when variable window settings were used in conjunction to the standard brain window. Mainali et al. [15], in their retrospective audit of 50 patients with acute ischemic stroke within 4.5 hours from symptom onset, reported significantly improved detection of early ischemic signs with the use of stroke window set at 30 WW and 35 WL after first applying standard window settings of 100 WW and 35 WL compared to the staff radiologist's report. However, the fact that the reading sessions in their study had different reviewers may have

 ISSN: Online 2790-1637, Print 2790-1629
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contributed to the difference in the detection rate of early ischemic signs rather than the use of the stroke window. Moreover, the circumstances of the reading sessions were also different. Unlike the radiology staff report, the reader knew beforehand that all cases had an acute stroke diagnosis, which may have also contributed to a higher number of ischemic signs detected.

In the present study, narrowing the window width did not significantly improve the sensitivity of non-contrast CT for acute stroke detection. This is most likely because image quality and diagnostic value have been steadily improved by developments in CT scan machines, such as spiral imaging characteristics, multi-slice capability, higher energy supply, and improved detectors [25], which in turn improved the conspicuity of early ischemic changes at the standard brain window. The results of this study indicate that the application of stroke window settings does not significantly improve the detection of acute stroke. Consequently, these findings do not support the routine use of stroke window review in the evaluation of all patients with suspected stroke. This has notable clinical implications, especially in emergency settings where timely diagnosis is needed and the additional review time with stroke window may not be feasible. On the other hand, it is important to consider that even small diagnostic gains can be clinically relevant in serious conditions like acute stroke. Stroke window may potentially aid less experienced readers or when clinical suspicion remains high despite a negative standard review. Therefore, selective use of stroke window may still offer value in the diagnostic process.

Early ischemic changes are important because, in addition to confirming the clinical suspicion of an infarct, they can provide prognostic information and guide stroke management. Parenchymal hypodensity is the most commonly observed early ischemic sign on non-contrast CT in acute stroke [20]. This was also observed in the present series, where the most important early ischemic sign was parenchymal hypoattenuation (72.4%), followed by grey-white matter differentiation loss (34.5%). The least positive early ischemic sign was the hyperdense artery sign (20.7%). There was no significant difference in the detection of these signs between the two window reviews. The ASPECTS score determines the extent of stroke lesion in pa-

 ISSN: Online 2790-1637, Print 2790-1629
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tients with acute MCA occlusion and hence determines the eligibility for thrombolytic therapy and endovascular intervention [26]. ASPECTS values were lower at the stroke window review compared to those at the default brain window, which means if stroke window settings were used after the default brain window in evaluating patients with acute MCA stroke, it would less likely alter the treatment plan for the patient, as it would not significantly increase the number of ischemic regions detected.

One of the advantages of this study is that the sample of cases reviewed by the radiologist was randomized at the time of image interpretation. It included all non-contrast CT brain studies performed within a specific period before the review of medical records for the inclusion process. This made the blinding of the reviewer complete and prevented any bias that could have resulted in increased reporting of positive signs if only patients with acute stroke were reviewed, thus making the results more representative of routine radiology practice.

Different approaches to maximize the useful visual information displayed on CT without needing to change window settings have been discussed in the literature. Image processing compresses CT image dynamic range to limited grayscale shades, maximizing visual information. Methods include non-linear CT windows, histogram equalization, adaptive histogram equalization, and contrast-limited adaptive histogram equalization. These algorithms operate on CT's entire dynamic range, but none has widespread clinical use [8]. Bier et al. [27] suggested that post processing of non-contrast CT with frequency selective non-linear blending significantly increases its sensitivity for detection of ischemic brain insult. Viriyavisuthisakul et al. [11], who evaluated window settings parameters for acute ischemic stroke by using deep learning models, found that the model could well predict with standard brain window settings. Deep learning methods, with the large number of regularly obtained brain scans, could be developed for ischemic lesion detection on CT without requiring lesion annotation [28].

5.Limitations.

The study has several limitations. First, this was a retrospective study, which might have affected the patient selection process, as the clinical information is reduced.

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Second, the exact time of the scan after the onset of the neurological symptoms is difficult to determine retrospectively, and a wider time window of 24 hours was opted for the study. Third, the cohort size was small. The limited patient cohort from a single-center study design with risks of potential selection bias may limit the generalizability of the results. Finally, the target for narrowing window settings was preset at a fixed value of 40 WW and 40 WL. Any other values suggested for stroke window settings were excluded from this study.

It is recommended to further validate the findings of the present study in the future with prospective multicentric studies with larger sample sizes and time windows of 6 hours, which would allow for more representation of the general population and higher scientific validity of the results.

6.CONCLUSION

The study showed that modern-generation CT has high sensitivity for acute stroke detection within 24 hours from symptom onset. Systemic assessment for early ischemic changes is a key to successfully recognizing them on imaging. The magnitude of superior sensitivity in reviewing images with stroke window settings (40/40 [WW/WL]) in addition to the default brain window (80/40 [WW/WL]) is small. It should be noted that in routine radiology practice, especially in busy radiology departments, radiologists tend to not use stroke window parameters when reviewing non-contrast CT of suspected stroke patients and instead use the default brain window without changing window parameters. The current study should therefore increase the confidence in daily radiology reporting that uses the standard brain window for assessing acute stroke.

7.ACKNOWLEDGMENTS

-No financial support.

-No conflict of interests.

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 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018