Journal of Population Therapeutics & Clinical Pharmacology

Transcranial Sonography vs. CT scans: A Prospective Study on Brain Midline Shift Assessment in Traumatic Brain Injury Cases

Rasheda El said Azzam[1], Abeer El Sayed Farhat[1], Manal Foad Abdelmoniem[1], Ayman Esmail Hussien[2], Warda Demerdash Khalifa Ali[3]

1. Assistant Professor of Anesthesia, Intensive Care and Pain Management, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt.
2. Lecturer of Anesthesia, Intensive Care and Pain Management, Faculty of Medicine for Girls, Al-Azhar University, Cairo, Egypt.
3. Assistant professor of Anesthesia, ICU and Pain Management, Faculty of Medicine for Boys, Al-Azhar University (Assiut Branch), Egypt.

Corresponding author email: Drrashedaazzam@gmail.com

Abstract

Background: Brain midline shift (MLS) is a crucial marker of intracranial issues requiring prompt diagnosis and intervention. While computed tomography (CT) scans are the gold standard, their repeated use in neurosurgical ICUs carries risks. Transcranial sonography (TCS) offers a noninvasive MLS assessment alternative.

Methods: A prospective cohort study involving 50 traumatic brain injury (TBI) patients was conducted to compare TCS MLS measurements with CT MLS measurements. Various clinical parameters, including Glasgow Coma Scale (GCS), ICU days, and ventilation days, were assessed alongside MLS sizes.

Results: TCS MLS exhibited a weak significant correlation with CT MLS ($r = 0.0483$, $p = 0.001$), while CT MLS demonstrated a moderate and highly significant correlation with TCS MLS ($r = 0.635$, $p < 0.001$). TCS MLS accurately detected MLS sizes, with mean measurements of 4.33 ± 2.11, whereas CT MLS had a mean of 5.43 ± 2.66.

Conclusion: This investigation underscores the potential of TCS as a valuable method for diagnosing MLS in TBI patients when compared to CT scans. Despite weak correlations, TCS provides a bedside, noninvasive option for early MLS detection, contributing to timely interventions. The study's findings suggest that TCS could reduce radiation exposure, enhance MLS assessment, and improve patient care in neurocritical settings.

Keywords: brain midline shift, computed tomography, transcranial sonography

Introduction

The accurate diagnosis and timely management of brain midline shift (MLS) are crucial concerning traumatic brain injury (TBI) [1]. MLS, often indicative of severe intracranial pathology, demands immediate intervention to prevent further complications and optimize patient outcomes [2].

Current diagnostic approaches heavily rely on computed tomography (CT) scans, which are pivotal in guiding treatment decisions for neurosurgical patients [3, 4]. However, the frequent use of CT scans, especially within the neurosurgical intensive care unit (ICU) setting, can pose risks due to patient transport and radiation exposure [5]. In this context, the exploration of alternative diagnostic modalities, such as transcranial sonography (TCS), gains significance. TCS offers the advantage of noninvasive visualization of intracerebral structures, enabling bedside assessment with minimal radiation exposure [6, 7].

This study aims to delve into the potential role of TCS in diagnosing MLS in TBI patients, comparing its effectiveness with CT scans. By addressing the challenges of MLS diagnosis and the limitations of current imaging techniques, this investigation contributes to enhancing patient care and safety in neurocritical settings.

Aim of the work

To investigate the role of TCS in diagnosing MLS in TBI compared with CT brain.

Material and method

Study Design

A prospective cohort study was conducted, involving the enrollment of 50 patients of both sexes. Participants were selected from the ICUs at the Faculty of Medicine, Al Zharaa University Hospital, based on their indication for brain CT scans.

Participants

Patients eligible for inclusion in the study were those admitted to the ICU with indications for brain CT scans due to TBI. Exclusion criteria encompassed patients with maxillofacial trauma and those with temporal subcutaneous hematoma or temporal bone defects.

Data Collection

A comprehensive approach to data collection was undertaken, encompassing the following steps:

1-Patient History

Detailed history-taking procedures were carried out, involving factors such as past medical history, and drug history.

2-Physical Examination

A complete physical examination was performed for each participant, including relevant clinical assessments.

3-Initial Assessment

TCS was performed to assess MLS for all participants. This was done in close correlation with admission CT scans. In cases where brain MLS was detected, appropriate medical or surgical interventions were initiated and subsequent TCS was conducted every 24 hours. Urgent TCS was also conducted in instances of deterioration or a decrease in consciousness level GCS (Glasgow Coma Scale). If an increase in brain MLS was observed, urgent brain CT scans were performed to enable timely surgical interventions, thereby reducing the associated morbidity, particularly in comparison to serial CT scans among neurosurgical ICU patients.

4. Imaging and Measurements

Plain brain CT scans were obtained for all participants, and MRI scans were conducted when indicated. We evaluated MLS using TCS through the temporal acoustic bone window, employing an ultrasound device with a low-frequency probe (2–4 MHz), namely the EMP 2100 model. We measured the distance between the external bone table and the center of the third ventricle on both sides and then MLS was computed as half of the difference between these measurements.

5. CT MLS Measurements

The measurement involved determining the space between the outer bone table and the midpoint of the third ventricle, precisely at the orbito-meatal plane, which was aligned with the sonographic measurement plane.

6. Neurological Examination

Participants underwent a comprehensive neurological assessment, including the Glasgow Coma Scale, to provide a detailed evaluation of their neurological status. 7. Laboratory tests

Blood glucose level, sodium, potassium, coagulation profile, kidney function, and complete blood count, were performed for all participants.

Ethical Considerations

Upon obtaining approval from the ethics committee, informed consent was obtained from the legal guardians of the participants.

Statistical Analysis

We conducted statistical analyses utilizing the Statistical Package for the Social Sciences (SPSS Inc.). Different statistical tests were employed, including the paired t-test to compare normally distributed quantitative variables between two time periods, the Pearson coefficient for establishing correlations among normally distributed quantitative variables, the Kruskal-Wallis test to compare groups with non-normally distributed quantitative variables, and the Receiver Operating Characteristic (ROC) curve to evaluate diagnostic performance and compute the area under the ROC curve for diagnostic accuracy assessment.

Sample Size

The sample size was calculated using the G Power software. Based on Motuel et al. (2014) [8], with an expected MLS incidence of 37%, TCS sensitivity of 84%, and
specificity of 85%, a sample size of 50 patients would yield a sensitivity power of 87%, specificity power of 98%, and a significance level of 0.05.

Results

Table 1. Demographic and Clinical Characteristics of Study Participants

Parameter	Mean ± SD	Range	Count	Percentage
Age (years)	40.65 ± 15.24	20 – 60		
Sex (n) (%) Male Female			35 15	70 % 30 %
MAP (mmHg)	95.12 ± 26.70	50-150		
HR (beat/min)	93.11 ± 18.29	62-135		
RR (breath/min)	20.15 ± 6.21	13-33		
TEMP (C°)	37.42 ± 0.55	36.5-38.6		
GCS	7.33 ± 1.75	3-9		
APACHE II score <20			38	76%
APACHE II score >20			12	24%

MAP: main arterial pressure, **HR:** Heart rate, **RR:** Respiratory rate, **TEMP:** Temperature, **GCS:** Glasgow Coma Scale

The participants' age distribution spans from 20 to 60 years, with a mean age of 40.65 years. There is a notable gender distribution with 70% males and 30% females. main arterial pressure ranges between 50-150 mmHg. Heart rate (HR) averages 93.11 beats per minute, while respiratory rate (RR) is around 20.15 breaths per minute. Body temperature (TEMP) is at an average of 37.42°C. The participants' GCS scores average 7.33, ranging from 3 to 9. The table also highlights that 76% of participants have an APACHE II score below 20, while 24% have a score above 20 (Table 1).

Table 2. Size Distribution Comparison: TCS MLS vs. CT MLS

TCS MLS		CT MLS	
Mean ± SD Range	4.33 ± 2.11 0.8-10	Mean ± SD Range	5.43 ± 2.66 1.3-11
TCS MLS < 2mm	7 (14%)	CT MLS < 2mm	4 (8%)
TCS MLS 2 - 4mm	21 (42%)	CT MLS 2-5mm	23 (46%)
TCS MLS 4 - 6mm	12 (24%)	CT MLS 5-8mm	16 (32%)
TCS MLS ≥ 6mm	10 (20%)	CT MLS ≥ 8mm	7 (14%)

For TCS MLS, the mean size is 4.33± 2.11, ranging from 0.8 to 10. The distribution of TCS MLS sizes includes 14% < 2mm, 42% 2 - 4mm, 24% 4 - 6mm, and 20% ≥ 6mm. For CT MLS, the mean size is 5.43 ± 2.66, ranging from 1.3 to 11. The CT MLS size distribution comprises 8% < 2mm, 46% 2 - 5mm, 32% 5 - 8mm, and 14% ≥ 8mm (Table 2).

Table 3. Correlation Between TCS MLS and CT MLS

	r	**P-value**
US MLS	0. 483	0.001
CT MLS	0.635	0.000

The correlation between TCS MLS and CT MLS is weak (r = 0.0483) but statistically significant (p = 0.001), suggesting a limited linear connection. On the other hand, the correlation between CT MLS and TCS MLS is moderate (r = 0.635) and highly statistically significant (p < 0.001), indicating a stronger positive linear relationship between the two variables (Table 3).

Table 4. Relation Between TCS MLS with GCS, Ventilation days, ICU days, and Survival

Variable	**TCS MLS ≤2mm**	**TCS MLS 2-4mm**	**TCS MLS 4-6mm**	**TCS MLS ≥6mm**	**P-value**
Outcome					
Survival	7 (100%)	21(100%)	4 (20%)	0 (0%)	<0.001
Death	0 (0%)	0 (0%)	8 (80%)	12 (100%)	
ICU days					
Median (IQR)	5 (5-6)	13 (9-14)	15 (12-18)	4 (1-20)	0.024
Range	5-6	6-16	9-24	1-22	
Ventilation days					
Median (IQR)	3 (2-3)	4 (3-5)	14 (12-19)	5 (1-20)	0.003
Range	2-4	2-5	5-23	1-21	
GCS					
Mean ± SD	7.98 ± 0.65	7.64 ± 0.50	6.95 ± 1.77	5.48 ± 1.79	0.002
Range	7-9	7-8	3-9	3-8	

The "Survival" outcome displays full survival in the ≤2mm and 2-4mm ranges, contrasting with survival percentages of 20% in the 4-6mm range and 0% in the ≥6mm range. The table also shows differences in ICU days and ventilation days across the size ranges, with statistically significant p-values indicating potential associations. Moreover, GCS scores tend to decrease as TCS MLS size increases (Table 4)

Table 5. Relation Between CT MLS with GCS, Ventilation days, ICU days, and Survival

Variable	**CT MLS ≤2mm**	**CT MLS <5mm**	**CT MLS <8mm**	**CT MLS ≥8mm**	**P-value**
Outcome					
Survival	4 (100%)	21 (95.5%) 2	4 (20%)	0 (0%)	<0.001
Death	0 (0 .0%)	(4.5%)	12 (80%)	7 (100%)	
ICU stays.					
Median (IQR)	5 (5-5)	12 (7-14)	18 (10-22) 1-22	2 (1-4)	0.001
Range	5-5	6-16		1-20	
Ventilation days					
Median (IQR)	3 (2-4)	4 (3-15)	19 (5-22)	2 (1-5)	0.000
Range	1-5	1-15	1-23	1-20	
GCS					
Mean ± SD	7.89± 0.66 7-9	7.60 ± 0.61 6-9	6.33 ± 1.40 3-8	5.22 ± 2.38	<0.001
Range				3-8	

Regarding the "Survival" outcome, CT MLS ≤2mm shows 100% survival, while CT MLS < 5mm indicates 95.5% survival and CT MLS <8mm demonstrates 20% survival, contrasting with 0% survival for CT MLS ≥8mm. In terms of ICU days, median values and ranges follow a pattern where CT MLS≤2mm has a median of 5 days and a range of 5-5, CT MLS< 5mm has a median of 12 days and a range of 7-14, CT MLS < 8mm has a median of 18 days and a range of 10-22, and CT MLS ≥8mm has a median of 2 days and a range of 1-4. The same trend can be seen in ventilation days. Additionally, GCS scores decrease as CT MLS values increase, with mean values ranging from 7.89 to 5.22. The provided p-values suggest statistical significance for the relationships observed (Table 5).

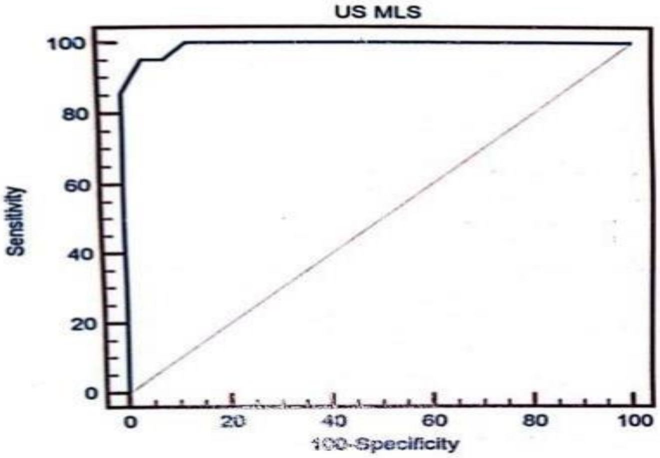

Figure 1. ROC curve for detection of a CT MLS> 5mm with TCS

Discussion

Our findings propose the feasibility of detecting MLS with a satisfactory level of precision among neurocritical patients through the application of TCS. Such an approach could potentially enhance the early identification and management of patients exhibiting substantial intracranial mass effects. Notably, TCS offers a noninvasive avenue, mitigating exposure to radiation and the risks associated with patient transport [9].

The primary objective of this study was to investigate the potential role of TCS in diagnosing MLS in TBI compared to conventional CT brain scans. The results provide valuable insights into the diagnostic capacity of TCS and its correlation with clinical parameters.

The study included 50 participants with a wide age range (20-60 years) and a balanced gender distribution which underscores the representative nature of the sample. MAP, HR, RR, body temperature, and GCS scores were measured, revealing the diversity in physiological status. Notably, the majority of participants had an APACHE II score below 20. The GCS scores provide a measure of neurological impairment, while the APACHE II score differentiation offers insights into the overall severity of patients' conditions.

Motuel et al. (2014) introduced sonography as a means to identify cerebral structures, particularly the third ventricle. Their pioneering work laid the foundation for MLS assessment using TCS [8].

The comparison of size distributions between TCS MLS and CT MLS is enlightening. The mean MLS sizes obtained through these methods indicate some differences, which could be attributed to the distinct imaging techniques or measurement accuracies. The MLS measurements taken through TCS and CT were not conducted concurrently. Since MLS can exhibit rapid fluctuations, it is plausible that the diminishing agreement between the two methods may, in part, be attributed to variations in MLS at distinct time intervals. This comparison highlights the potential diagnostic utility of TCS in assessing MLS. Likewise, in prior investigations about MLS measurements obtained via TCS and CT [10, 11], a minor difference between the two measurements was observed, demonstrating an acceptable concurrence.

The correlation analysis revealed modest associations between MLS measurements obtained through TCS and CT scans, implying that these methods might yield differing MLS values. Our results are consistent with Motuel et al. (2014), who established a significant correlation between sonography and CT MLS measurements [8]. Conversely, in contrast to our findings, Llompart et al.'s (2004) study compared MLS measurements using Transcranial color-coded duplex sonography (TCCDS) and cranial CT scans in patients with various intracranial hemorrhages. This study unveiled a robust correlation coefficient between TCCDS and CT measurements, underscoring sonography's potential for precise MLS assessment [12].

Additionally, the outcomes and associations observed across various subgroups based on TCS MLS measurements were examined. In the context of survival outcomes, it is notable that all patients with TCS MLS measurements ≤ 2mm or between 2mm and 4mm achieved survival, whereas, in the 4-6mm TCS MLS subgroup, 20% of patients did not survive. This percentage increased significantly to 80% in the subgroup with TCS MLS measurements exceeding 6mm, underlining a potentially significant correlation between larger TCS MLS measurements and mortalities. Furthermore, the results demonstrated trends in the duration of ICU stay and the number of days requiring mechanical ventilation, indicating that patients with higher TCS MLS measurements tend to experience longer stays in the ICU and require extended periods of ventilation support. In terms of the GCS, lower mean values are associated with larger TCS MLS measurements, implying a potential impact on neurological status as MLS increases. These findings suggest the potential clinical utility of MLS assessment in aiding treatment decisions and outcome predictions in TBI cases.

Our study observed a consistent underestimation of CT MLS by TCS (5.43 ± 2.66mm with TCS vs. 4.33 ± 2. 11 mm with CT). Despite this discrepancy, TCS demonstrated good sensitivity and specificity (95.1% and 95.9%, respectively) in detecting significant MLS (>5mm in CT) using a 3.9mm threshold, with the underestimation becoming less pronounced as MLS size decreased.

Conclusion

This investigation underscores the potential of TCS as a valuable tool for diagnosing MLS in TBI patients when compared to CT scans. Despite weak correlations, TCS provides a bedside, noninvasive option for early MLS detection, contributing to timely interventions. The study's findings suggest that TCS could reduce radiation exposure, enhance MLS assessment, and improve patient care in neurocritical settings. Further research is warranted to validate the clinical utility and diagnostic accuracy of TCS in MLS assessment.

References

1. V., V., et al., *Automated Detection and Screening of Traumatic Brain Injury (TBI) Using Computed Tomography Images: A Comprehensive Review and Future Perspectives.* International Journal of Environmental Research and Public Health, 2021. **18**(12): p. 6499.
2. Jiang, C., et al. *Midline Shift vs. Mid-Surface Shift: Correlation with Outcome of Traumatic Brain Injuries*. in *2019 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*. 2019. IEEE.
3. Liao, C.-C., Y.-F. Chen, and F. Xiao, *Brain Midline Shift Measurement and Its Automation: A Review of Techniques and Algorithms.* International Journal of Biomedical Imaging, 2018. **2018**: p. 4303161.
4. Hooshmand, M., et al. *Automatic Midline Shift Detection in Traumatic Brain Injury*. in *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. 2018.
5. Theophilus, S.C., et al., *Neuroimaging in the Neuro-ICU*, in *Neurointensive Care: A Clinical Guide to Patient Safety*, K.E. Wartenberg, K. Shukri, and T. Abdelhak, Editors. 2015, Springer International Publishing: Cham. p. 299-312.
6. Kapoor, I., et al., *Comparison between Transcranial Sonography and Computerized Tomography Scans to Assess the Midline Shift in Patients with Traumatic Brain Injury.* Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine, 2023. **27**(1): p. 64.
7. Bittencourt Rynkowski, C. and J. Caldas, *Ten Good Reasons to Practice Neuroultrasound in Critical Care Setting.* Frontiers in Neurology, 2022. **12**.

8. Motuel, J., et al., *Assessment of brain midline shift using sonography in neurosurgical ICU patients.* Critical Care, 2014. **18**: p. 1-8.
9. Helmy, T.A., M.A. Abdelhady, and H.A. Ahmed, *Assessment of brain midline shift using sonography in neurocritical patients.* Research and Opinion in Anesthesia & Intensive Care, 2019. **6**(2): p. 200-205.
10. Kiphuth, I.C., et al., *Sonographic monitoring of midline shift predicts outcome after intracerebral hemorrhage.* Cerebrovascular Diseases, 2012. **34**(4): p. 297-304.
11. White, H. and B. Venkatesh, *Applications of transcranial Doppler in the ICU: a review.* Intensive care medicine, 2006. **32**: p. 981-994.
12. Llompart Pou, J.A., et al., *Monitoring midline shift by transcranial color-coded sonography in traumatic brain injury: a comparison with cranial computerized tomography.* Intensive care medicine, 2004. **30**: p. 1672-1675.