Egyptian Journal of Biophysics and Biomedical Engineering
https://ejbbe.journals.ekb.eg/

The effects of oblique scanning on susceptibility weighted Imaging (SWI) visualization of Nigrosome-1 used in Neurodegenerative disease diagnosis

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OBJECTIVE: Susceptibility-weighted imaging (SWI) is a pivotal tool in neurological imaging, offering unparalleled insights into brain microstructures, particularly in Parkinson's disease (PD) diagnosis. This study investigates the influence of slice orientations specifically True Axial and Anatomical Axial on the detection of the Swallow Tail Sign (STS) using SWI. Originally known as High-resolution venography, SWI is now crucial for detecting tissue anomalies in neurodegenerative diseases like PD. A study focused on improving visualization of brain structures related to Parkinson's disease using optimized SWI scans. Materials and Methods: 20 patients were scanned, but only 12 met the criteria for analysis. Results indicated a preference for True Axial orientation in visualizing structures, but the difference was not statistically significant. This suggests True Axial orientation may improve the visualization of structures in the brain. Discussion: The present findings support a potential practical bias toward the True Axial orientation to achieve improved STS detection accuracy. But they should be investigated further with larger cohorts to validate and refine imaging protocols. Optimal slice orientations in SWI may help improve diagnostic accuracy in PD, especially at centers where 3T scanners are not accessible.

Keywords: MRI; SWI; Neuro Imaging; Oblique orientation; Parkinson disease(PD).

Introduction

Susceptibility-weighted imaging (SWI) is a powerful imaging technique that allows researchers to visualize the microstructural landscape of the brain [1-3]. SWI was originally developed as a method for high-resolution venography in 1997, but it quickly became clear that the technique could do much more. By 2004, SWI had evolved into susceptibility-weighted imaging [4]. SWI is so named because its ability to reveal intricate tissue properties and anomalies stems from its remarkable sensitivity to minute magnetic field distortions specifically, The variations in magnetic susceptibility of brain tissue give rise to distinct differences in the images produced [5-7], [1, 8].

SWI relies on a specially tailored 3D gradient echo sequence the details of which we'll come to shortly. By capturing both magnitude and phase information, SWI allows researchers to detect even subtle magnetic susceptibility differences among tissues and thus to see structural properties and anomalies in neural tissue that other imaging techniques miss [9,10].

In recent years, the growing recognition of the Swallow Tail Sign (STS) has driven researchers to investigate its utility further. SWI is a widely used MRI technique that accentuates magnetic susceptibility differences among tissues due to dephasing of magnetic moments [11-12]. The technique yields images of the brain that are not only rich in morphological detail, but that also show the positional relationship of

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Received: 21/11/2024; Accepted: 02/12/2024
DOI :10.21608/EJBBE.2024.338367.1079

different structures relative to each other (such as the superior colliculus versus the substantia nigra), thus facilitating the detection and characterization of the nigrosomes of substantia nigra especially Nigrosome-1 which STS is located [11-13]. Using SWI, radiologists can now identify the STS in almost all healthy controls (98–100%) and in a large percentage of patients with Parkinson disease (up to 86%) [13-14]. This unique configuration serves as a beacon for clinicians, providing a tangible and dependable marker to differentiate individuals afflicted by Parkinson's disease from healthy subjects [14].

The recognition and characterization of the STS represents a significant advance in the PD diagnostic landscape. Its presence or absence in SWI scans not only aids in the accurate diagnosis of disease but could also serve as an early indicator, dictating a change in treatment strategies and disease management [15-16].

The aim of our study is to shed light on the slice orientations in SWI, especially as it relates to the appearance and visibility of the so-called STS. We propose an extensive review of SWI data obtained from routine MRI brain scans to investigate the effect of slice orientation in elucidating this key marker in PD.

Materials and Methods

Patients

All patients who took part in this study gave verbal consent after being given approval by the research ethics committee. The group comprised 12 people (ten males, two females), whose average age was 40.58±17.24 years, and who had undergone brain MRI examinations. Most often, these MRIs were done when patients presented with various clinical symptoms such as vertigo and headache

MRI Data Acquisition

A 1.5 Tesla MR machine (Philips Achieva DS) with a head and neck coil was used for all the MRI scans. The brain routine protocol included several sequences such as fluid-attenuated inversion recovery (FLAIR) axial plane, T1-weighted imaging (T1 W) sagittal plane, diffusion weighted imaging (DWI) axial plane and susceptibility-weighted phase imaging (SWI) axial plane. The following SWI sequence parameters were used: field of view FOV=232 x 200 mm2, matrix size=272 x 200 voxels; voxel dimension = 0.85mm x 1mm x 2 mm. The sequence utilized a TE of 40ms, a TR of 51 ms, and a 20° flip angle, incorporating 1.2 SENSE to minimize scan duration. The images were acquired with a thickness of 2 mm across 130 slices, culminating in a 5-minute scan time.

In this image, calcifications come out as hyperintense for diamagnetic elements while deoxy hemoglobin has hypointensity. Each subject was imaged using two SWI procedures: one with a slab selection parallel to the main magnetic field (True-Axial), and the other with an anatomical alignment with respect to the AC-PC line (Anatomy-Axial).

Study Population and Inclusion/Exclusion Criteria

Initially, 12 healthy individuals were included in the study who underwent brain MRI as a routine checkup. For comparability and consistency with specific criteria, strict inclusion and exclusion criteria were used.

Inclusion Criteria

Patients undergoing SWI for diagnostic evaluation, Availability of SWI scans performed under both True Axial and Anatomical Axial orientations.

Exclusion Criteria

Patients with co-existing neurological conditions, SWI scans lacking clarity or compromised quality in either orientation and Incomplete datasets or missing records for either orientation. Using these criteria, a subset of 12 patients was identified as meeting the strictest standards, having appropriate SWI scans both under True Axial and Anatomical Axial orientations. These 12 patients constituted the final cohort for further analysis, ensuring consistency and reliability in the comparative assessment of the swallow tail sign presence.

TABLE 1. Left Side Contingency.

Left Side STS Presence	True Axial	Anatomical Axial
STS Present	8	4
STS Absent	4	8

TABLE 2. Right Side Contingency.

Right Side STS Presence	True Axial	Anatomical Axial
STS Present	**6**	**4**
STS Absent	**6**	**8**

TABLE 3. Both Sides Contingency.

Both Sides STS Presence	True Axial	Anatomical Axial
STS Present	5	2
STS Absent	7	10

TABLE 4. Comparison between True Axial and Anatomical Axial orientations for detecting the swallow tail sign .

Comparison	McNemar's Test (p-value)
Left Side: True Axial vs. Anatomical Axial	p = 0.25
Right Side: True Axial vs. Anatomical Axial	p = 0.5
Both Sides: True Axial vs. Anatomical Axial	p = 0.125

Statistical analysis

The twelve patients who were eligible, generated a very strong dataset to compare STS presence between True axial and Anatomical Axial orientations. A McNemar test was used for comparing the presence of swallow tail sign in true axial orientation and anatomical axial orientation. These tables represented the number of patients observed with or without STS under both these orientations. When this matched categorical data set was subjected to the McNemar Test difference testing, it was expected that it would show any significant change in the rate at which this sign appears in either orientation.

The figures derived from McNemar Test because of our study are indicators of how different those two populations are. A level of significance required for rejection is 0.05, and we use a p-value less than 0.05 to reject the null hypothesis if it is present. The statistical analysis sought to provide key insights into whether a specific slice orientation could be preferred for detecting SWI's STS, which could impact on clinical practice and enhance diagnostic accuracy in PD assessment by SWI.

Results

Employing the McNemar test, a specialized method for analyzing paired categorical data, a 2x2 contingency table was formulated. This table encapsulated counts of patients manifesting the presence or absence of the swallow tail sign under both orientations as figure 1. The McNemar test's application to this paired categorical dataset aimed to discern significant differences in the proportion of the sign's presence between the two orientations.

Left Side - True Axial vs. Anatomical Axial Orientation:

The comparison between the appearance of the swallow tail sign on the left side under True Axial and Anatomical Axial orientations revealed no statistically significant difference (McNemar's test, $p = 0.25$). The p-value of 0.25 suggests that the observed differences in the sign's presence between these orientations are not statistically significant in this cohort of 12 patients as shown in figures 2a ,2b and 2c.

Right Side - True Axial vs. Anatomical Axial Orientation:

Similarly, the comparison of the swallow tail sign appearance on the right side under True Axial and Anatomical Axial orientations demonstrated no statistically significant distinction (McNemar's test, $p = 0.5$). The p-value of 0.5 indicates a lack of significant differences in the presence of the sign between these slice orientations among the same cohort figures 3a ,3b and 3c.

Both Sides - True Axial vs. Anatomical Axial Orientation:

Exploring the appearance of the sign on both sides simultaneously under True Axial and Anatomical Axial orientations exhibited no statistically significant variation (McNemar's test, $p = 0.125$). With a p-value of 0.125, the comparison suggests no significant differences in the combined presence of the sign between these orientations within this patient group as shown in figures 4a ,4b and 4c.

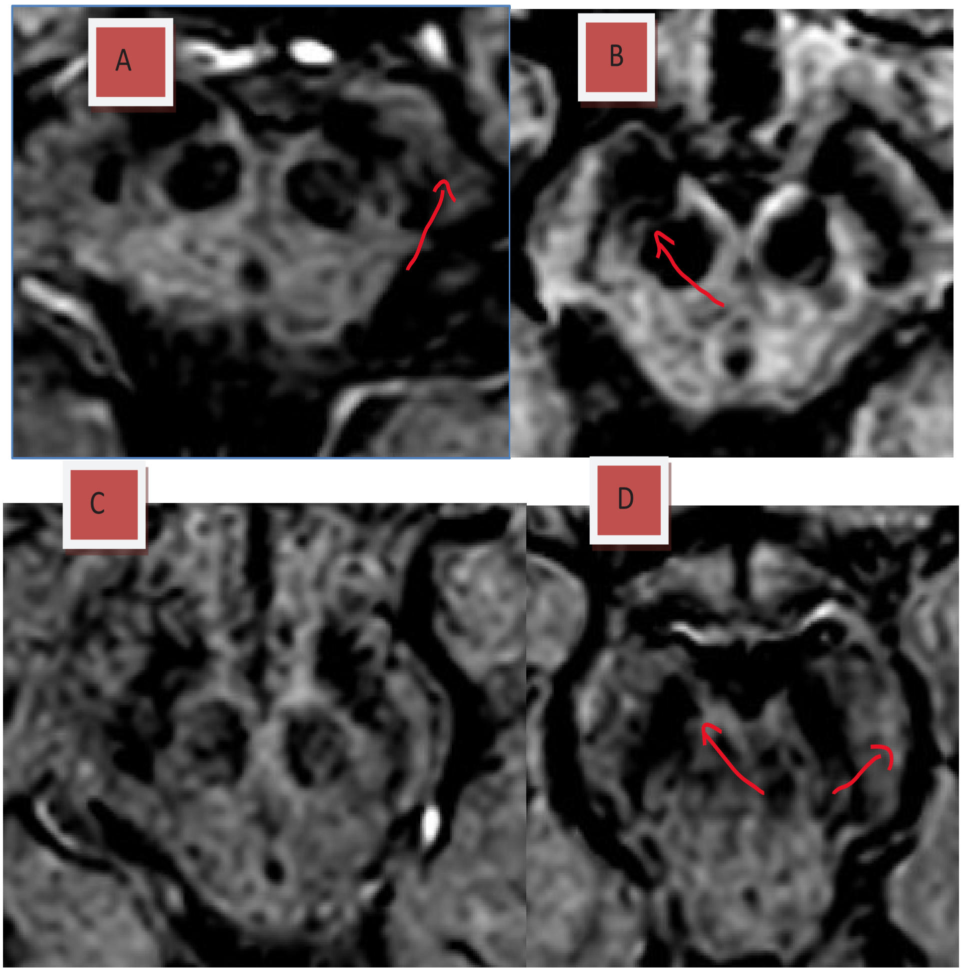

Fig.1. Representation of Swallow Tail Sign Presence (indicated by red arrow) and Absence. Description: (A) Indicates the presence of the swallow tail sign on the left side. (B) Marks the presence of the swallow tail sign on the right side. (C) Denotes the absence of the swallow tail sign on both sides. (D) Represents the presence of the swallow tail sign on both sides.

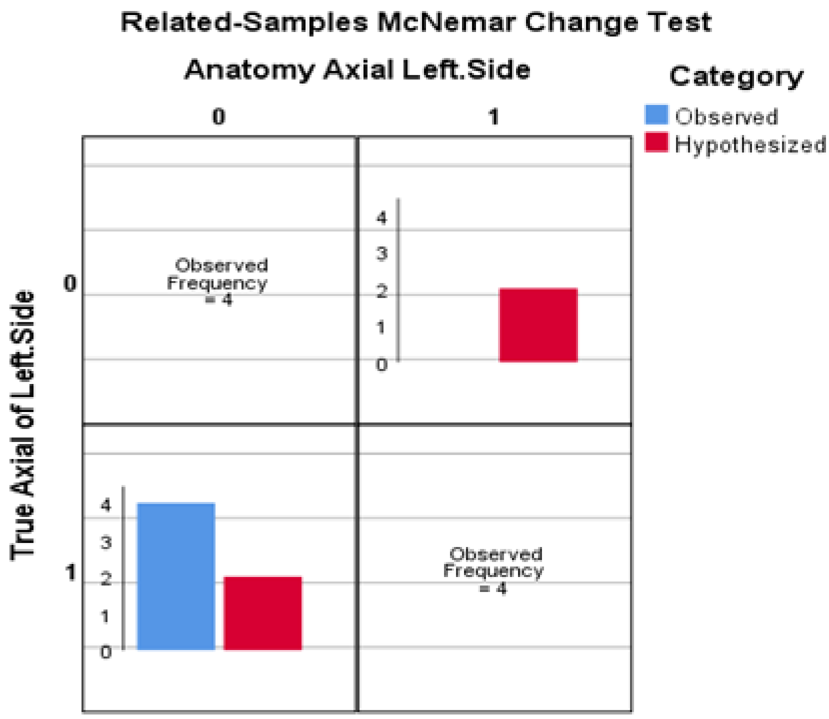

Fig. 2a. Represented mcnemar test between true axial vs anatomy axial in left side of swallow tail sign.

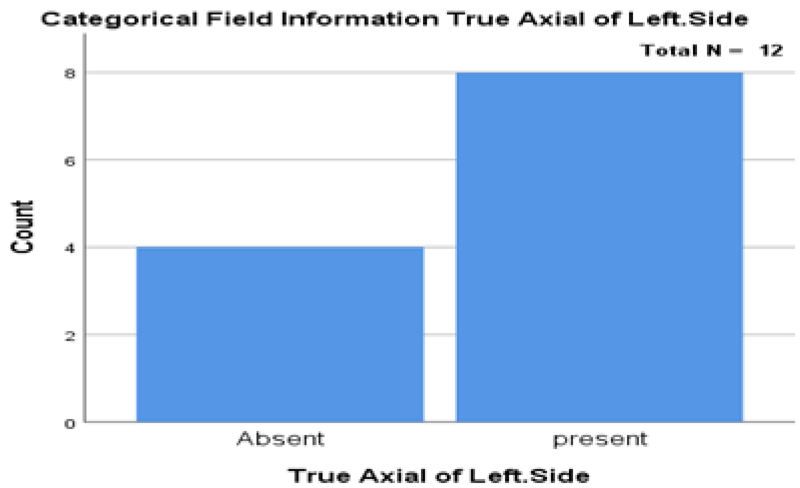

Fig.2b. Displays the categorical distribution of left-side Swallow Tail Sign (STS) presence or absence within the True Axial group. The chart illustrates the distribution across different categories: Indicates the presence of STS on the left side. And the absence of STS on the left side

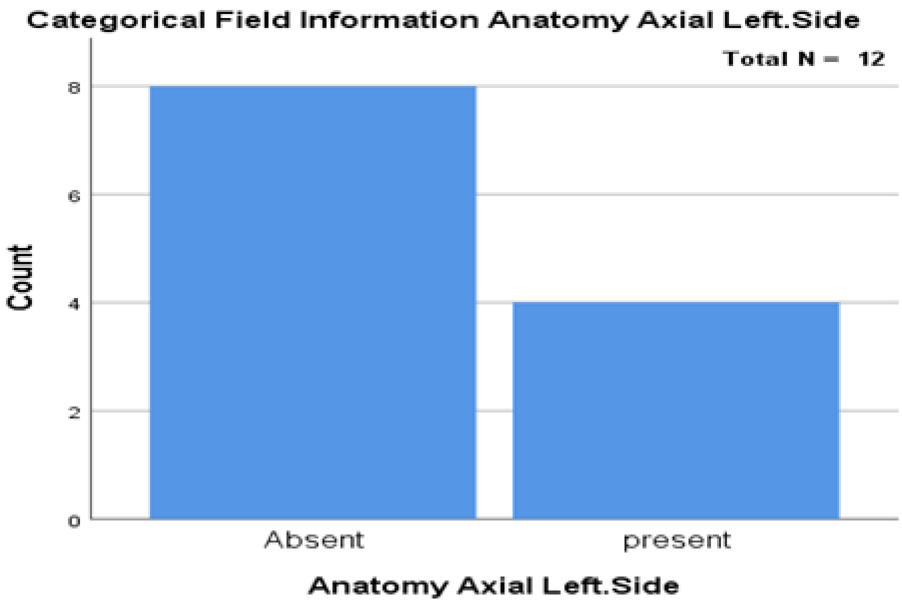

Fig.2c. Displays the categorical distribution of left-side Swallow Tail Sign (STS) presence or absence within the Anatomical Axial group. The chart illustrates the distribution across different categories: Indicates the presence of STS on the left side. And the absence of STS on the left side

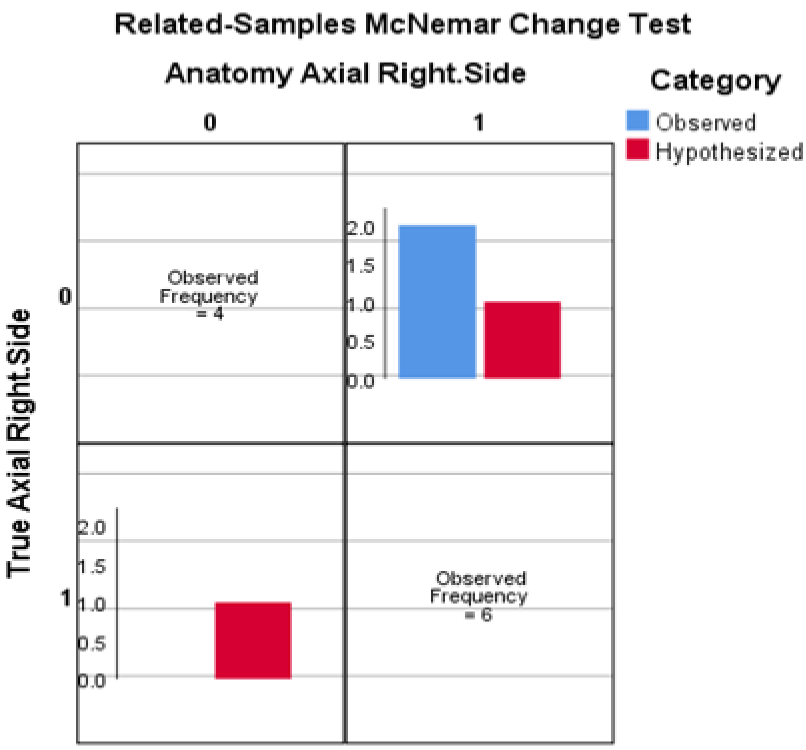

Fig.3a. Represented McNemar Test between True Axial vs Anatomy Axial in Right side of Swallow tail sign.

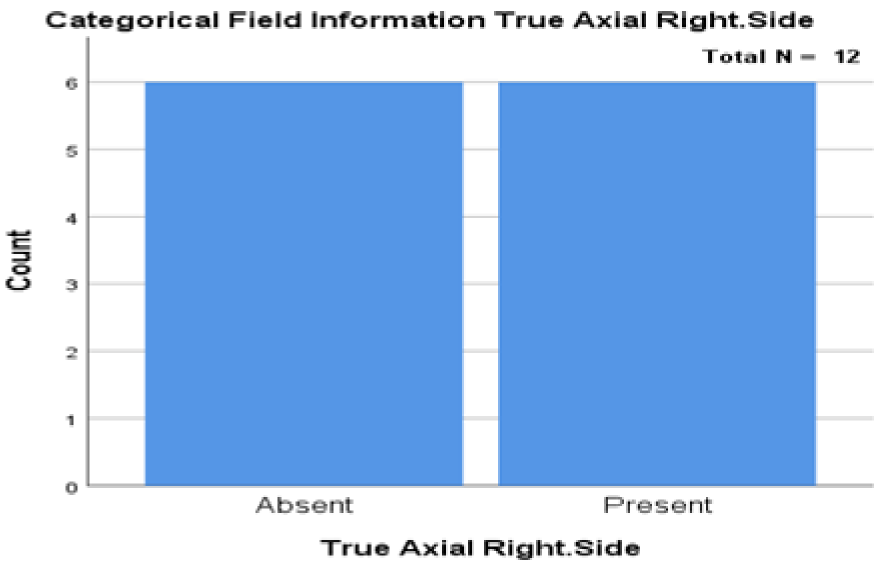

Fig.3b. displays the categorical distribution of Right-side Swallow Tail Sign (STS) presence or absence within the True Axial group. The chart illustrates the distribution across different categories: Indicates the presence of STS on the Right side. And the absence of STS on the Right side

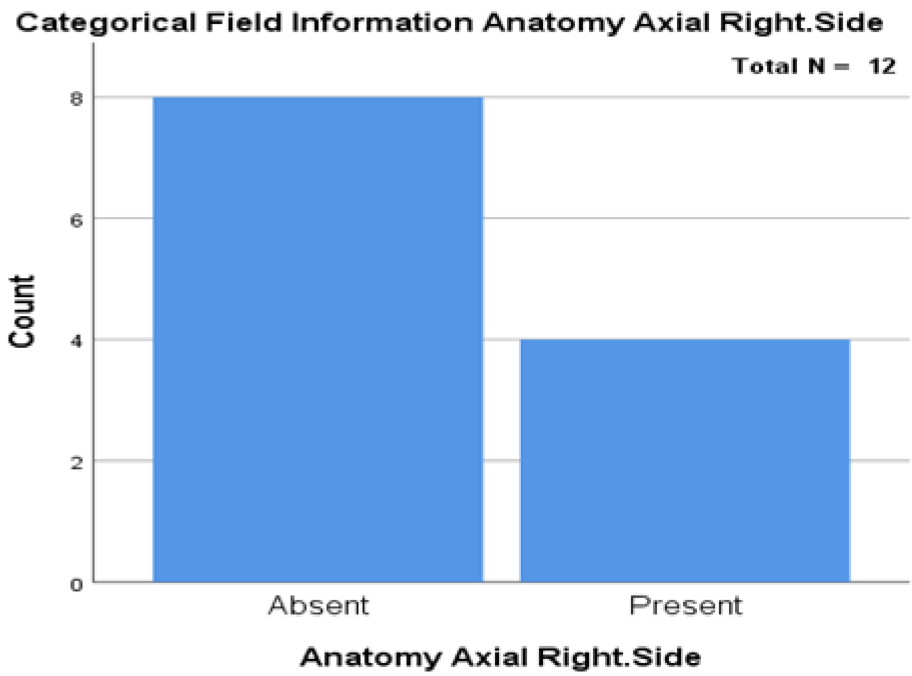

Fig.3c. displays the categorical distribution of Right-side Swallow Tail Sign (STS) presence or absence within the Anatomy Axial group. The chart illustrates the distribution across different categories: Indicates the presence of STS on the Right side. And the absence of STS on the Right side.

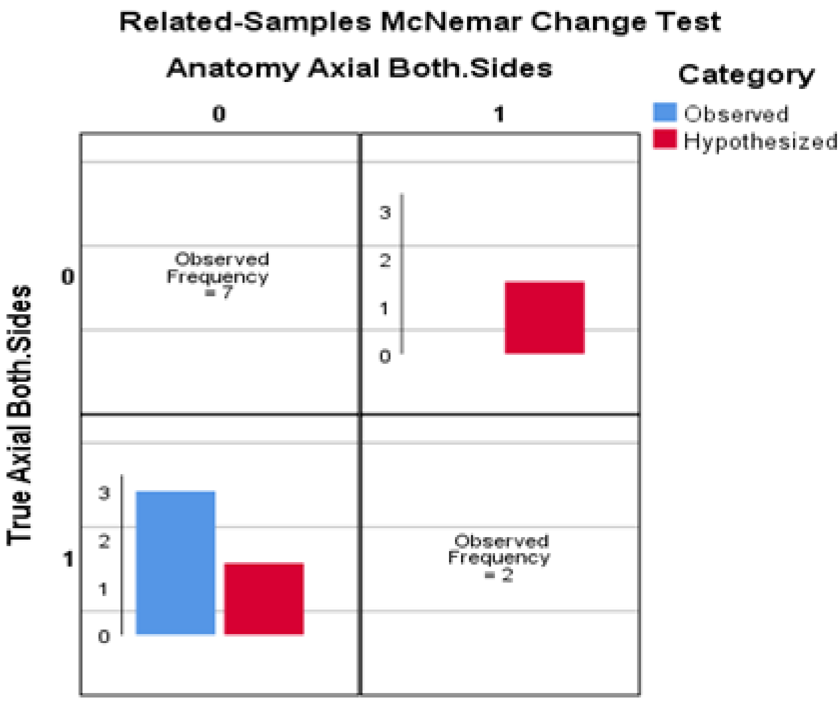

Fig.4a. Anatomy. Represented McNemar Test between True Axial vs Axial in Both sides of Swallow tail sign.

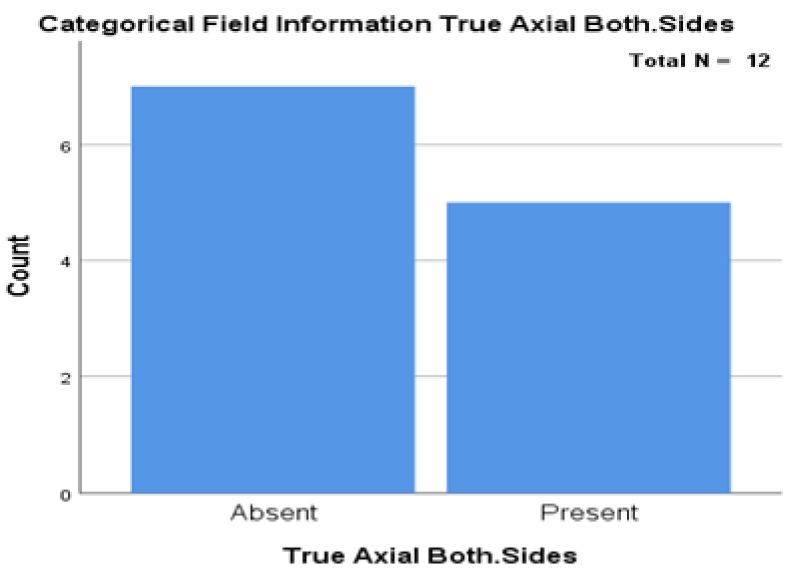

Fig.4b. displays the categorical distribution of Both-sides Swallow Tail Sign (STS) presence or absence within the True Axial group. The chart illustrates the distribution across different categories: Indicates the presence of STS on the Sidse. And the absence of STS on the Both sides.

Discussion

SWI holds significant value in neurological imaging by enabling the visualization of intricate structures such as the STS. Its sensitivity to susceptibility changes plays a crucial role in identifying substances vital for characterizing Parkinson's disease" [19], [9].

The comparative analysis between True Axial and Anatomical Axial orientations did not yield statistically significant differences in STS detection. However, from the results emerged a notable trend favoring the True Axial orientation. True Axial visualized the sign in 8 of 12 cases compared to 4 of 12 in Anatomical for the left side. Similarly, for the right side, True Axial visualized the sign in 6 of 12 cases compared to 4 of 12 in Anatomical. For both sides, True Axial depicted the sign in 5 of 12 cases compared to 2 of 12 in Anatomical.

These observations translated to specific ratios: 2:1 for the left side, 3:2 for the right side, and 5:2 for both sides (True Axial: Anatomical Axial), demonstrating a consistent trend favoring True Axial orientation in visualizing the STS.

To the best of our knowledge, no previous studies have explored the effect of slice orientation on visualizing the STS in SWI. Understanding the impact of slice orientation on imaging outcomes, particularly on lower Tesla machines like the 1.5 Tesla used in this study, is crucial for refining imaging protocols. Optimizing parameters and orientation choices could potentially enhance diagnostic accuracy, especially in settings limited to lower Tesla strengths" [18,20].

The lack of statistical significance in differences between orientations suggests comparable diagnostic efficacy in detecting the STS. While the observed trend leans toward improved accuracy in the True Axial orientation [17,20], further investigations with larger cohorts are warranted for validation and generalization.

Conclusion

In this comparative study between True Axial and Anatomical Axial orientations for Swallow Tail Sign (STS) detection using susceptibility-weighted imaging (SWI), no statistically significant differences were found. However, a noteworthy trend emerged favouring the True Axial orientation.

Even though the results weren't statistically significant, the data hint at a trend where the True Axial orientation seems to offer better accuracy for spotting the STS compared to the Anatomical orientation. The ratios 2:1 on the left, 3:2 on the right, and 5:2 overall suggest a consistent edge for True Axial in visual clarity.

While these findings aren't conclusive, they point to a practical advantage in using True Axial for detecting this sign in Parkinson's disease assessments. It seems that True Axial might be the better choice, but more research with larger groups is needed to confirm this trend and fully understand how orientation affects diagnostic accuracy.

Funding

This study did not receive or obtain any particular grant at all from any sources in the public, private, or non-profit sectors.

Author contributions

T. Elsayed: study conception and design, acquisition of data, analysis and interpretation of data, drafting of manuscript. A. Eissa: study conception and design, analysis and interpretation of data, drafting of manuscript, critical revision.

Availability of data and materials

Available.

Declarations

Ethical approval and consent to participate

All experimental protocols were approved by the ethical in our institution. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Competing interests

We have no conflict of interest to declare.

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تأثيرالفحص المائل على التصوير المرجح القابلية للإصابة (SWI) لنيغروسوم-١ المستخدم في تشخيص الأمراض التنكسية العصبية

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يعد التصوير المرجح الحساسية (SWI) أداة مهمة جدا بل و محورية في عملية التصوير العصبي، حيث يقدم إمكانية لتوفيررؤى لا مثيل لها في لمعظم التراكيب الدقيقة للدماغ، و يزداد هذا الأمر وضوحا و تجليا في حالة تشخيص مرض باركنسون (PD). الدراسة الحالية تحاول ان تبحث في تأثير تغير أتجاهات الشرائح و على وجه التحديد المحور الحقيقي والمحور التشريحي على اكتشاف علامة ذيل البجعه (STS) باستخدام تقنية SWI. و خلال هذا الفحص يتم استخدام التصوير الوريدي عالى الدقة باستخدام الأشعة السينية (SWI) و الذي يعد حاليا أمرا حاسما للكشف عن التغير الحادث في الأنسجة في الأمراض التنكسية العصبية مثل مرض باركنسون (PD). الدراسة الحالية ركزت على تحسين تصوير هياكل الدماغ المتعلقة بمرض باركنسون باستخدام التصوير المقطعي المحوسب و المحسن. و من أجل هذا فقد تم فحص ٢٠ مريضا، ولكن ١٢ فقط من المشاركين في الدراسة تم استيفاء معايير التحليل معهم. و قد أشارت النتائج إلى تفضيل الإتجاه المحوري الحقيقي في هياكل التصور، حيث انه بالفعل قام بتحسين رؤية الهياكل المختلفة في الدماغ. و النتائج الحالية تدعم و بقوة الإتجاه الى التحيز بشكل عملي نحو التوجه المحوري الحقيقي لتحقيق دقة أفضل في الكشف عن STS. ولكن ينبغي إجراء المزيد من التحقيقات مع مجموعات أكبر للتحقق من بروتوكولات التصوير وتحسينها. قد تساعد أتجاهات الشرائح المثالية في SWI على تحسين دقة التشخيص في PD، خاصة في المراكز التي لا يمكن لها توفير أجهزة التصوير الحديثة ذات ٣ تسلا.