Medical Science

pISSN 2321–7359; eISSN 2321–7367

Volumetric appraisal of the superior temporal gyrus in normally functioning human brain, using magnetic resonance imaging

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To Cite:
Elamin AAE, Eltahir MIM, Elghazaly EA, Idris SA, El-Elhaj A, Elmasalmi EMM, Omer MIE. Volumetric appraisal of the superior temporal gyrus in normally functioning human brain, using magnetic resonance imaging. Medical Science, 2022, 26, ms236e2347.
doi: https://doi.org/10.54905/disssi/v26i124/ms236e2347

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Peer-Review History
Received: 11 June 2022
Reviewed & Revised: 12/June/2022 to 20/June/2022
Accepted: 20 June 2022
Published: 21 June 2022

Peer-review Method
External peer-review was done through double-blind method.

URL: https://www.discoveryjournals.org/medicalscience

ABSTRACT

Background: The volume and morphology of the superior temporal gyrus (STG) of the human brain can be affected by age. Its quantitative assessment might be aiding the clinicians. *Objective:* To estimate the STG volume in MRI using DICOM viewer in adults deprived of structural brain abnormality, to correlate the volume with age, and to determine its variations between/and within the sexes. *Material and Methods:* A retrospective study was performed in Al-Amal Hospital, Sudan (April 2021 and March 2022). STG volume was delineated along the entire STG borders. Using SPSS version 25.0 data were processed. *Results:* It included a MRI brain of 50 adult patients (equal genders); their mean age was 33.12± 8.29 years (range, 20 to 49 years). STG volume was adversely interrelated with age ($r = -0.318$ and $P=0.024$), significantly differed bilaterally within sexes ($P = 0.000$), and was greater on the left in both genders. A significant gender difference was observed regarding STG volume, $p = 0.000$. *Conclusion:* DICOM can be used to assess the STG morphometrically to detect any pathological variations, based on volume changes.

Keywords: Superior Temporal Gyrus; Volumetric; Age; Gender; DICOM software

1. INTRODUCTION

The superior temporal gyrus (STG) along with the middle temporal gyrus (MTG), and inferior temporal gyrus (ITG), are horizontally located on the temporal lobe, and separated by two horizontal sulci; the superior and inferior temporal (Campero et al., 2014). The STG was defined as the area between the superior temporal sulcus (STS) and the Sylvian fissure, where its posterior

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boundary being the junctional point of the horizontal ramus of the Sylvian fissure and the ascending ramus of the STS (Taylor et al., 2005). At the temporal pole of the temporal lobe, STG joins ITG whereas MTG does not reach the temporal pole (Ribas, 2010). Determination of superior temporal gyrus orientation in relation to skull bones is clinically fundamental; the gyrus lies below the squamous suture, while the lateral fissure is at the suture level (Campero et al., 2014).

STG and sulcus begin to grow at 20-23 weeks after conception, while at 20-22 weeks the main hemispherical structure of the temporal lobe begins to develop (Goldstein et al., 2017). STG contains the auditory cortical area, which is responsible for processing and frequencies of sounds (Leaver et al., 2016), and the Wernicke's area plays a major role in recognizing and comprehending language and is usually found on the left side of the brain (Ardila et al., 2016). Furthermore, STG is an essential structure involved in social cognition (Bigler et al., 2007) audiovisual integration and perception of emotion (Robins et al., 2009). Damage to the rostral portion of STG decreases motion perception in visual hemifields equally (Karnath, 2001) whereas; the deactivation of the middle part of STG impacts the exploration of the visual search (Gharabaghi et al., 2006).

Lesions in the cortical region of the posterior STG cause conduction aphasia, which damages the phonemic portion of speech output (Buchsbaum et al., 2001), while bilateral lesions are known to cause purely verbal deafness in most individuals(Nuñez et al., 2020). There are numerous previous studies regarding the measurement of STG volume, most of them were concerned the Schizophrenia (Ohi et al., 2016; Rajarethinam et al., 2004; Rajarethinam et al., 2000; Ratnanather et al., 2013; Sun et al., 2009) and autism, (Bigler et al., 2007; Jou et al., 2010; Kobayashi et al., 2020). The volumetric measurement of the temporal lobe cortex thickness varies and changes with the increasing age of an individual (Seiger et al., 2018).

Since STG cortex contains important functional areas, the study of this eminent zone would be of anatomical, physiological, and pathological interest. The study served as an estimate to the normal volume of STG, using MRI in adult Sudanese subjects, to correlate the volume with age and gender, and to study bilateral variations in both sexes.

2. MATERIALS AND METHODOLOGY

Study design and population

A non-probability total coverage, retrospective study had been carried out in Al-Amal Hospital, Khartoum state, Sudan, between April 2021 and March 2022. MRI scans of patients who met the inclusion criteria were evaluated for STG volume estimation, after all ethical considerations had been met.

Inclusion criteria

Adult Sudanese patients aged between 20 to 60 years. This is because the human brain tends to fully grown until the age of twenty (Johnson et al., 2009), and the atrophic changes usually commences after the age of sixty (Lafta and Imeer, 2019). Acceptance of the pre-given informed consent; the required brain MRI images from individuals whom were confirmed to be free of brain abnormalities and structural diseases

Exclusion criteria

MRI scans of patient age less than 20 years and more than 60 years; The MRI scans of patients with a previous history of temporal lobe lesions, other neurological diseases and brain anomalies.

Procedure

MRI images were taken at the radiology department, using Philips Achieva 1.5 tesla MRI Machine. MRI images of the brain were obtained at T1 weighted, 2 mm slice thickness, then after treated by Digital Imaging and Communications in Medicine (DICOM) viewer version 3.0 (OsiriX; Geneva, Switzerland) for STG volume measurement. The data were collected by manual tracing STG edges in a sagittal brain MRI images using the DICOM. Manual STG delimitation was started from the back of the upper edge of the gyrus and continued forward along the upper edge to the temporal pole and then backward along its lower edge to the starting point. Therefore, when the tracer reaches the start point, volume measurements were displayed (Figure 1).

Statistical Analysis

The estimated data of STG volume were studied by SPSS version 25.0. Qualitative data had been expressed as percentage and mean, whereas, the quantitative one were explored as means and compared between groups. Bilaterally, STG volumes analysis had been carried out utilizing t-test. An independent t-test was applied to match STG volumes between the sexes. The Pearson correlation coefficient (Pearson's r) was used to show the correlation between age and STG volume. It was considered to be significant if the p-value was less than 0.05.

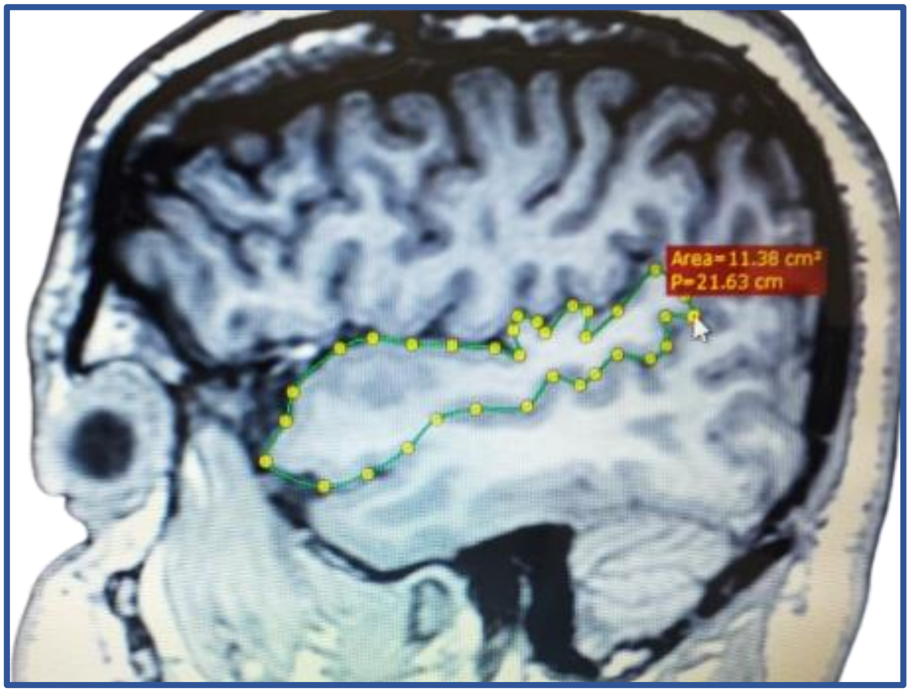

Figure 1 Delineation of STG on a brain MRI scan, the yellow dots indicate the edges of the gyrus.

3. RESULTS

Out of all 50 MRI brain images, 25 (50%) were male and 25 (50%) female patients. The male age ranged between 20-45 (mean, 31.40±8.16) years, whereas, in female it was ranged between 22-49 (mean, 34.84± 8.42) years. Table 1 shows the mean age, and STG's mean and volume. The mean volume of the left STG in males and females was 10.84±0.82and 9.68 ± 0.84cm^3 respectively. The mean volume measured on right STG in males and females was 10.38±0.94 and 9.29±0.90cm3 respectively. The left STG volume was remarkably greater in both gender (P= 0.000). Mean total STG volume in males and females was 21.22±1.74 and 18.97±1.69 respectively. The mean STG volume in males on either side was greater than that on the corresponding female's side. Study had expressed a remarkable difference between sexes in term of STG total volume (p= 0.000).

A significant negative correlation was observed between age and STG volume on the right side of both sexes (r = −0. 318; p = 0.024) (Figure 2). On the other hand, an insignificant negative correlation was observed between age and STG volume on the left side of both sexes (r = −0.271; p = 0.057), which means, the age has little effect on the left STG volume of both sexes (Figure 3).

Table 1 The mean age (in year), the mean and volume of the STG (cm^3)

STG	Male		Female		*Total*	
	Min-Max	Mean ±SD	Min-Max	Mean ±SD	Min-Max	Mean ±SD
Left STG Volume (cm^3)	9.33-12.63	10.84±0.82	7.88-11.45	9.68 ± 0.84	8.61-12.04	10.26±0.83
Right STG Volume (cm^3)	9.09-12.61	10.38±0.94	7.15-11.61	9.29±0.90	8.12-12.11	9.84±0.92
Total STG Volume (cm^3)	18.42-25.24	21.22± 1.74	15.03-23.06	18.97±1.69	16.72-24.15	20.10±1.72
Age (in year)	20.00-45.00	31.40±8.16	22.00-49.00	34.84± 8.42	21.00-47.00	33.12±8.29
Total	*25 (50%)*		*25 (50%)*		*50 (100)*	

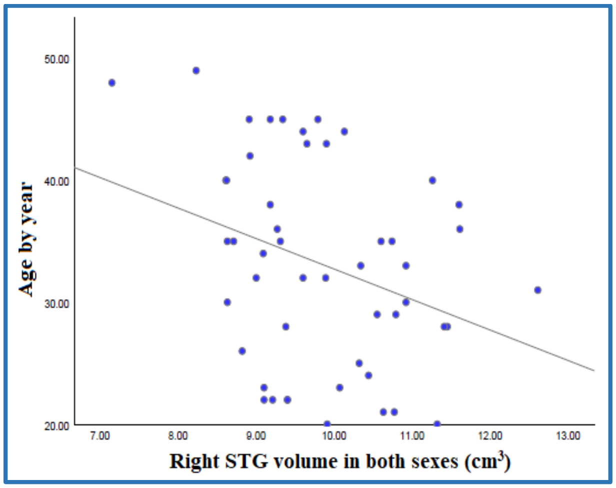

Figure 2 Shows the correlation of age with the right STG volume of both genders

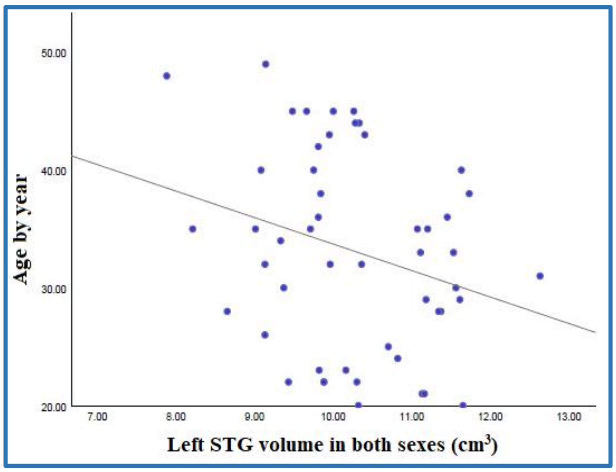

Figure 3 shows the correlation of age with the left STG volume of both genders.

4. DISCUSSION

Volumetric measurement is important to detect age-related changes in the STG; such changes can be observed at varying degrees in all brain regions (Trollor aValenzuela, 2001). This was confirmed by a long-term study reported by Scahill et al., (2003) found that these changes in the brain were not uniform on two MRIs separated by one year or two. Thus, by measuring the normal volume of brain regions we can assess these changes. Many previous STG-related studies have been conducted to compare STG volume in normal healthy control individuals with STG in patients with mental illness (Matsumoto et al., 2001; Rajarethinam et al., 2004). The current study measured the STG volume in the healthy temporal lobe of Sudanese individuals to determine the normal STG volume, and to compare it with age and gender groups.

In the current study the mean right STG volume was 9.84±0.92, this was almost similar to that reported by Keshavan et al., (1998), whereas it was lower than others (Matsumoto et al., 2001; Murad et al., 2021; Takahashia et al., 2010). Similar observation was found in the contralateral side. STG volumes in the most of aforementioned studies were larger than the results of the current study, probably their STG volume was examined in younger age groups. In a volumetric study of STG in 20 healthy individuals, Rajarethinam et al., (2000) reported that STG volume was significantly larger on the left than on the right, 23.34±3.7 and 21.32±3.4 respectively.

Similar result was obtained in another morphometric study of STG in 72 healthy individuals which performed by Takahashi et al., (2006) found that the left and right STG volumes were 12641 ± 1670 and 10917 ± 1465 respectively. The above results were consistent with the results of our study where we found that the STG size was greater on the left than on the right, the result suggests that participants in the current study are most likely right-handed. In contrary, De Bellis et al., (2002a) when studied STG volume in 98 healthy subjects, the right STG volume was 23.36 ± 2.68 and the left was 22.19 ± 2.75, with a conclusion that the right

STG is greater than the left. As well, in his another studyin 61 healthy persons, reached to confirmation of right STG is greater than the left (De Bellis et al., 2002b).

In the regards to correlation of STG volume with age, the current study addressed the impact of age on the STG, as left STG volume was contrariwise interrelated with age which was in concordance with Rajarethinam et al., (2004), in which the left STG volume was contrariwise interrelated with age in healthy subjects ($r = –0.40$; $p = 0.04$). Whereas in the study by Bartzokis et al., (2001), who focused on the temporal lobe and its grey matter where they examined age-related changes in the temporal lobes and found a significant volume reduction ($r = -0.35$: $P = 0.003$). Additionally, they found significant correlation decrease in the temporal lobes grey matter ($r = -0.48$; $P<.001$).

On the other hand, Torii et al., (2012) investigated the effect of aging on grey matter in 24 healthy younger and older groups, they found that grey matter in STG of the older was notably low($p = 0.008$), this finding confirmed that the influence of age on STG volume reduction is more pronounced in older subjects than younger. To our knowledge, no study has examined the association of STG volume to genders. Despite that, in most studies different brain regions in males were greater than those in females (Filipek et al., 1994; Sowell et al., 2007).

Limitation of the study

The current study provided no information on participants' hand laterality (preferring of one hand over the other).

5. CONCLUSION

Morphometric analysis using DICOM would be beneficial to determine the normal and age-related changes in STG. In the current study, no symmetrical volume was observed in the STG in either sex. The size of the STG on the left side is greater than the right. The males have a larger size than females. The advancing age negatively affects the size of the STG. We recommend further studies to substantiate the obtained results with the possibility of measuring the STG volume sub-regions as well as grey and white matter. The study's finding could open new research gates in older age groups with the introduction and screening of STG followed by interval STG, and the rate of volume change could signal an early occurrence of structural brain diseases such as Alzheimer, it could lead to future planning of their management.

Acknowledgement

We have endeavor to express our deepest gratitude to all those who offered their assistance. Special thanks and appreciation to the Radiology Department of Al-Amal Hospital in Khartoum, Sudan. In addition, we would like to overwhelm our thanks to Dr. Amani Elfaki who invented the idea of this study.

Author's contribution

AAEE participated extensively in writing manuscript, conducted the statistical analysis, and designed the graphs and tables. MIME conceived, discussed, presented the idea for the manuscript, and participated in writing discussion section. EAE, AELE, and EMME all contributed equally to the writing manuscript. MIEO collected data and identified similar articles for inclusion. SAI assist with editing, reviewing, and preparation of the manuscript for publishing. Contributors agreed on latest version of manuscript draft.

Ethical considerations

Study proposal had been accepted by research's ethical commission of the National University (Code: NU-REC/08-021/09). Permission was also received from the Hospital administration. Patient's confidentiality was maintained throughout the study, using anonymous images and without patient's identifier.

Funding

This study has not received any external funding.

Conflicts of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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