Assessment of the Length of the Anterior and Posterior Commissure Lines According to Gender and Age

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Abstract

Aim: There are variations in the size and shape of the skull based on factors such as race, age, and gender. The anterior and posterior commissures are significant brain regions that serve as essential reference points for stereotactic and functional neurosurgical procedures, human brain mapping, and medical imaging techniques. Our study analyzed the length of the anterior-posterior commissure (AC-PC) with these demographic factors in patients who underwent deep brain stimulation (DBS) in the Turkish population.

Method: A total of 101 individuals, comprising 64 men and 37 women, were included in the study. Data were collected through magnetic resonance imaging performed according to the DBS protocol, with the anterior commissure (AC) and posterior commissure (PC) markings conducted using the StealthStation™ S8 Planning program. Receiver Operating Characteristic (ROC) analysis was performed to distinguish between male and female AC-PC measurements.

Results: The mean age of all participants was 60.32±11.31 years (range: 30-85), and the average AC-PC distance was 24.18±2.03 mm (range: 20.01-28.7). The AC-PC distances of males (24.83±1.986 mm) were statistically significantly greater than those of females (23.06±1.592 mm). A weak positive correlation was observed between the ages and AC-PC distances of the participants ($r=0.432$, $P<0.001$). According to the results of the univariate regression analysis, each additional year of age in males was associated with an increase of 0.083 mm (95% CI: 0.045 – 0.121) in AC-PC distance ($R^2=0.235$, $P<0.001$).

Conclusion: A comparison of data obtained from other studies indicates that the AC-PC distance in individuals of Turkish descent is nearly similar to that of the Asian population, yet shorter than that observed in Caucasian populations and even shorter than in Hispanic populations. These findings highlight the variation in AC-PC distances associated with ethnic origin.

Keywords: Anterior commissure, posterior commissure, stereotactic surgery.

Cinsiyet ve Yaşa Göre Ön ve Arka Komissür Hatlarının Uzunluğunun Değerlendirilmesi

Öz

Amaç: Irk, yaş ve cinsiyet gibi faktörlere bağlı olarak kafatasının boyutu ve şekli değişir. Ön ve arka komissürler, stereotaktik ve fonksiyonel nöroşirürjik prosedürler, insan beyni haritalaması ve tıbbi görüntüleme teknikleri için temel referans noktaları görevi gören önemli beyin bölgeleridir. Çalışmada, Türk popülasyonunda derin beyin stimülasyonu (DBS) uygulanan hastalarda bu demografik faktörlerle ön-arka komissür (AC-PC) uzunluğu analiz edildi.

Yöntem: Çalışmaya 64 erkek ve 37 kadın olmak üzere toplam 101 kişi dahil edildi. Veriler, StealthStationTM S8 Planning programı kullanılarak gerçekleştirilen ön komissür (AC) ve arka komissür (PC) işaretlemeleriyle DBS protokolüne göre gerçekleştirilen manyetik rezonans görüntüleme yoluyla toplandı. Erkek ve kadın AC-PC ölçümlerini ayırt etmek için Alıcı Çalışma Karakteristiği (ROC) analizi yapıldı.

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Bulgular: Tüm katılımcıların yaş ortalaması 60,32±11,31 yıl (aralığı: 30-85) ve ortalama AC-PC mesafesi 24,18±2,03 mm (aralığı: 20,01-28,7) idi. Erkeklerin AC-PC mesafeleri (24,83±1,986 mm) kadınlarınkinden (23,06±1,592 mm) istatistiksel olarak anlamlı derecede daha büyüktü. Katılımcıların yaşları ve AC-PC mesafeleri arasında zayıf bir pozitif korelasyon gözlendi ($r=0,432$, $P<0,001$). Tek değişkenli regresyon analizinin sonuçlarına göre, erkeklerde her ek yaş yılı AC-PC mesafesinde 0,083 mm'lik (95% CI: 0,045 – 0,121) bir artışla ilişkiliydi ($R^2=0,235$, $P<0,001$).

Sonuç: Diğer çalışmalardan elde edilen verilerin karşılaştırılması, Türk kökenli bireylerde AC-PC mesafesinin Asya popülasyonuna neredeyse benzer olduğunu, ancak Kafkas popülasyonlarında gözlemlenenden ve hatta Hispanik popülasyonlardan bile daha kısa olduğunu göstermektedir. Bu bulgular, etnik kökenle ilişkili AC-PC mesafelerindeki çeşitliliği vurgulamaktadır.

Anahtar Sözcükler: Ön komissür, arka komissür, stereotaktik cerrahi.

Introduction

The anterior commissure (AC) and posterior commissure (PC) are prominent anatomical features that provide indirect guidance for locating intracerebral structures. Additionally, the inter-commissural line has proven to be a dependable reference for conducting stereotactic surgery. The swift progression of neuroimaging technologies has enabled a comprehensive analysis of the anatomical structures of the anterior and posterior commissures[1].

A Review of the Evolution of AC-PC Measurements

Following the shift from animal neurophysiological studies to the clinical application of stereotaxy in humans, neurosurgeons addressed the challenge of variability in the correlation between external skull landmarks and intracerebral targets[2]. Spiegel and Wycis accomplished this by utilizing intracerebral reference points, which have been essential for advancing human stereotactic techniques[3]. Talairach and his team observed that cerebral structures may not consistently align with skull landmarks, but the AC-PC line can be a reliable reference for locating intracerebral nuclei[4]. Schaltenbrand and Bailey created an atlas of the human brain that streamlined this system by designating the AC-PC line, which resides in the median (sagittal) plane, as one axis, and establishing a perpendicular line at the midpoint between the two commissures as the other was the pioneer in describing a prototype stereotactic frame designed for computer tomography (CT) scanners[5]. Subsequently, Lars Leksell became the first stereotactic neurosurgeon to modify his system to incorporate CT and magnetic resonance imaging (MRI). MRI has largely supplanted CT due to its superior anatomical visualization, allowing for precise identification of the AC-PC line and targets[6]. To mitigate spatial distortions in MRI, a novel approach has been developed that integrates CT imaging with image correlation software on a dedicated workstation[7-9]. In this study, we examined the significance of the AC-PC length in stereotactic surgeries concerning age and gender in the Turkish population.

Material and Methods

Patients who underwent cranial MRI at 1.5T and 3T for deep brain stimulation intervention between September 2016 and August 2024 at two different institutions. The AC-PC distance has been measured in T1w imaging with confirmation in multiplanar reconstruction and T2w imaging. The imaging parameters for T1w imaging consists of 256×256×170 or 512x512x180 matrices, with a spatial resolution of 0.9-1 mm in all

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dimensions. Then the data was installed to Stealth Station S8 Surgical Navigation System, which assists in planning target coordinates for deep brain stimulation. The system automatically measured the AC-PC distance after the AC and PC were indicated on the images. For each subject, AC and PC points were controlled and manually corrected by a board certified neuroradiologist, if needed.

The data were evaluated using SPSS software (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequencies and percentages (%), while continuous variables with normal distributions were reported as mean ± standard deviation (SD). The normality of the data was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests, depending on sample size. The Student's t-test was applied to the normally distributed data to compare the two independent groups. Receiver Operating Characteristic (ROC) analysis was conducted to determine the optimal cut-off value for distinguishing AC-PC measurements between males and females. The area under the ROC curve (AUC) was assessed, along with 95% confidence intervals, and the AUC values were classified as follows: 0.9-1 indicates excellent performance, 0.8-0.9 denotes good performance, 0.7-0.8 is considered fair, 0.6-0.7 reflects poor performance, and 0.5-0.6 represents very poor performance. The optimal cut-off value was identified using the Youden index, which maximizes sensitivity and specificity to determine the most appropriate threshold in the ROC analysis. Based on data normality, Pearson correlation analysis was employed to assess the relationship between age and AC-PC values. Univariate regression analysis examined the variation in AC-PC measurements according to age. A P-value of <0.05 was considered statistically significant for all tests.

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Results

The study analysed data from 101 patients, including 64 (63.4%) males and 37 (36.6%) females. The mean age of all cases was 60.32±11.31 years (range: 30-85), and the mean AC-PC length was 24.18±2.03 mm (range: 20.01-28.7). Statistical findings comparing AC-PC distances between genders are presented in Table 1. The AC-PC distances of males (24.83±1.986 mm) were statistically significantly higher than those of females (23.06±1.592 mm) (Table 1).

Table 1. Statistical findings for the comparison of AC-PC distances between genders

	Male (n=64)	**Female (n=37)**	***P* values**
AC-PC distance (mm)	24.83±1.986	23.06±1.592	**<0.001**

Student's t-test with mean±standard deviation (SD)

AC-PC: Anterior commissure-posterior commissure

According to the results of the ROC analysis aimed to determine the optimal cut-off point for the differentiation of AC-PC distances between genders, the discriminatory power of the AC-PC distance was significant at a fair level with an AUC 95% CI = 0.770 (0.675 – 0.865) (P<0.001). The best cut-off point for the AC-PC distance was determined as 23.65

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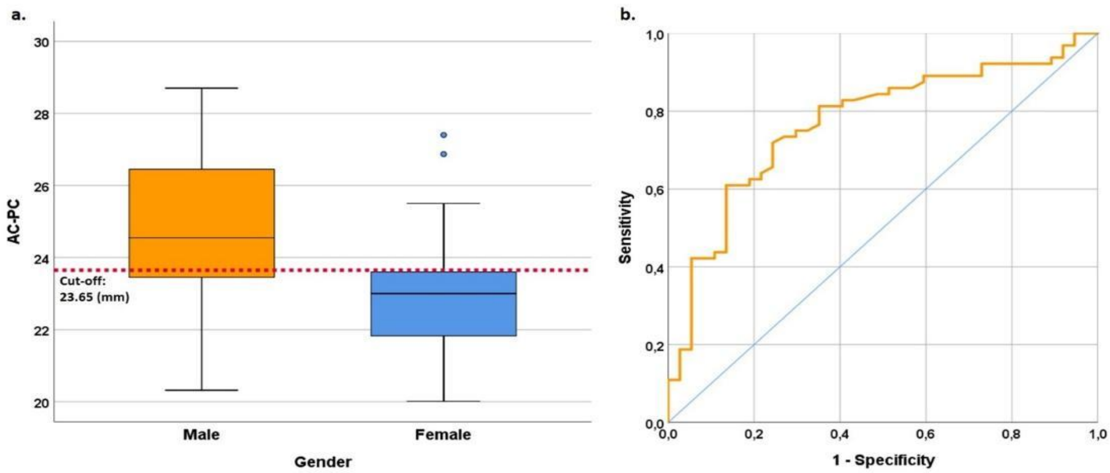
mm (Sensitivity: 71.88% (95% CI: 60.86 - 82.89), Specificity: 75.68% (61.85 - 89.50), PPV: 83.64% (73.86 - 93.41), NPV: 60.87% (46.77 - 74.97), and Accuracy: 73.27% (64.64 - 81.90)). The distribution of AC-PC distances between gender groups is shown in Figure 1.a, and the ROC curve is shown in Figure 1.b.

Figure 1. a. Boxplot showing the distribution of anterior commissure-posterior commissure (AC-PC) distances between genders

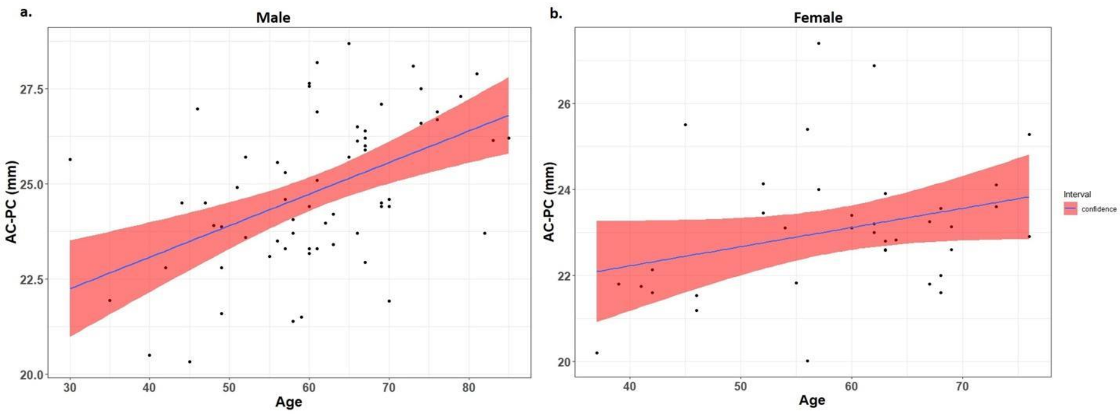
b. ROC curve to determine the best cut-off point for discrimination of AC-PC distances between genders



A weak positive correlation was found between all patients' ages and AC-PC distances (r=0.432, $P<0.001$). When evaluated separately by gender, a moderate positive correlation was found between the ages and AC-PC distances of male patients (r=0.485, $P<0.001$, Figure 2.a), while no significant correlation was found between the ages and AC-PC distances of female patients (r=0.300, $P=0.071$, Figure 2.b). According to the results of univariate regression analysis, each one-year increase in age was associated with a 0.083 (95% CI: 0.045 – 0.121) mm increase in AC-PC distance in males ($R^2=0.235$, $P<0.001$).

Figure 2. a. Scatter plot with regression curve showing the relationship between age and anterior commissure-posterior commissure (AC-PC) distances in male patients

b. Scatter plot with regression curve showing the relationship between age and AC-PC distances in female patients



Boxplots showing the distribution of AC-PC distances according to the World Health Organization's (WHO) age classifications (Young Adult: 25-44, Middle-Aged Adult: 45-59, Late Middle-Aged Adult: 60-64, Young Old: 65-74, Middle Old: 75-84) are shown for males in Figure 3.a and for females in Figure 3.b. In addition, descriptive statistics of AC-PC distances according to age classifications are presented in Table 2.

Figure 3. a. Box plots showing the distribution of anterior commissure-posterior commissure (AC-PC) distances of male patients according to World Health Organisation (WHO) age classifications

b. Box plots showing the distribution of AC-PC distances in female patients according to World Health Organisation (WHO) age classifications

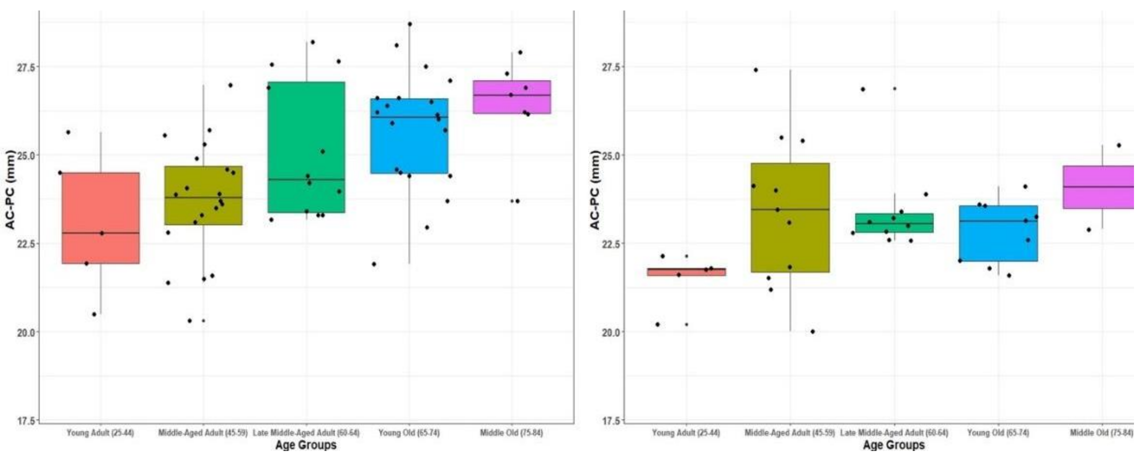


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Table 2. Descriptive statistics of AC-PC distances between genders according to World Health Organisation (WHO) age classifications

	Male				Female			
Age groups	**n**	**Mean±SD**	**min**	**max**	**n**	**Mean±SD**	**min**	**max**
25-44	5	23.07±2.04	20.50	25.64	5	21.5±0.75	20.20	22.13
45-59	20	23.71±1.64	20.32	26.97	11	23.41±2.19	20.01	27.40
60-64	12	25.1±1.93	23.17	28.20	10	23.43±1.27	22.58	26.87
65-74	20	25.7±1.7	21.92	28.70	9	22.85±0.89	21.60	24.10
75-84	7	26.41±1.34	23.70	27.90	2	24.09±1.68	22.90	25.28

AC-PC: Anterior commissure-posterior commissure, SD: Standard deviation

Discussion

Contemporary stereotactic functional neurosurgery procedures employ a coordinate framework based on the AC and PC locations[10]. Preoperative target identification can be accomplished through direct or indirect localization, especially for deep brain stimulation interventions. Surgeons can directly select targets by visually referencing the patient's MRI scan or by utilizing automated selection techniques as described in the work of D'Haese et al[11]. Indirect target selection employs standardized coordinates derived from anatomical atlases like the Schaltenbrand-Wahren atlas. This method is often utilized when targets are not identifiable on MRI scans[5]. The anterior and posterior commissures serve as key reference points in the conventional stereotactic coordinate framework. According to the established conventions of the Schaltenbrand-Wahren atlas, the AC and PC are identified as two specific points in the midsagittal plane that exhibit the minimal distance within the ventricles between the commissures. The mid-commissure point (MC), the central point along the AC-PC line, is frequently utilized as the origin for the AC-PC reference framework[5]. Both commissures are recognized as reliable and consistent anatomical structures within the brain, and they can be readily visualized using current MRI systems, including those operating at 1.5T or 3.0T[12]. Given that the AC and PC are situated at the front and rear of the deep brain, respectively, and are separated by a significant distance, they serve as important reference points for the indirect localization of brain structures, particularly in the context of stereotactic surgery[13-15].

Generally, the AC-PC distance most commonly reported is within the range of 21 mm to 28 mm[12]. Previous studies involving a population from Nepal, consisting of 47 individuals, reported an average AC-PC distance of 24.86 ± 2.08 mm for the Nepalese group[12]. In a study involving 211 patients focused on inter-racial analysis, the measurements for 12 Asian patients were reported as 24.6 ± 2.21 mm. In comparison, 160 Caucasian patients had 25.2 ± 2 mm measurements, and 35 Hispanic patients measured 23.6 ± 1.98 mm[1]. According to these results, the AC-PC distances in individuals of Asian and Nepalese descent are similar to the values observed in our study. In contrast, the Caucasian population exhibited more extensive measurements. These findings highlight the variation in AC-PC distance associated with ethnic background.

A statistically significant positive correlation, albeit weak, was observed between the ages of all patients and their AC-PC distances. Similar to our observation of a linear increase in AC-PC distance with advancing age, Lee et al. and Dabadil et al. have reported comparable results[1,12]. When the correlation was assessed separately by gender, a statistically significant moderate positive correlation was found between the ages of male patients and their AC-PC distances ($r=0.485$, $P<0.001$). Conversely, a significant correlation was not found between the ages of female patients and their AC-PC distances.

Lee et al. observed that the AC-PC length continues to increase until the age of 75 years in Caucasians, while in Hispanics, the maximum distance is reached at 45 years, followed by a gradual decline after that[1]. We found a similar result; according to the results of the univariate regression analysis, each additional year of age in men was associated with an increase of 0.083 mm (95% CI: 0.045 – 0.121) in the AC-PC distance. One of the main factors believed to contribute to the increase in AC-PC distance with age is the gradual decline of gray matter in the brain occurring between the ages of 20 and 50[16]. Furthermore, alterations in the cerebrospinal fluid (CSF) regions and the decrease in the volume of the cerebral hemispheres with aging may account for the variations observed in inter-commissural distances[17].

In this study, the AC-PC distances for men (24.83±1.986) were statistically significantly greater than those for women (23.06±1.592). Research on brain volume indicates that men have an average of 91 ml more cerebrum volume and 20 ml more cerebrospinal fluid volume than women[18]. This difference may be attributed to the fact that men typically possess larger brain and cerebrospinal fluid (CSF) volumes.

Conclusion

These findings highlight the variation in AC-PC distance associated with ethnic background. In conclusion, caution should be exercised when utilizing existing atlases in functional stereotactic procedures.

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