

Age Estimation from closure of some cranial sutures (coronal, sagittal, and lambdoid) in a sample of Egyptian population using computed tomography: retrospective study

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Abstract

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Background: Accurate age estimation is essential in forensic anthropology, bioarcheology, and medico legal investigations. Recent advancements in CT imaging have enabled detailed examination of cranial sutures, offering valuable insights. **Aim:** This study aimed to correlate the relationship between age and closure of cranial sutures and to estimate average age of closure of each suture (coronal, sagittal, and lambdoid) using CT imaging on a sample of Egyptian population. **Materials & methods:** Total number of 100 CT cases, 20 years and beyond were included in the study, and divided equally into five age groups with an age interval of 10 years; Group 1 (20-30 yrs), group 2 (>30-40 yrs), group 3 (>40-50 yrs), group 4 (>50-60 yrs) & group 5 (> 60 yrs). Assessment of suture closure was done according to the Frederic Rating Scale on CT imaging. The acquired data was statistically analyzed. **Results:** The current study revealed a positive correlation between age and cranial suture closure, also we observed that sagittal suture closes earlier and begins closure first through its second part (S2) at around 38.82 ± 11.62 followed by coronal sutures where the second part (C2) is the first to start closure with mean age of 43.29 ± 16.58 and then lambdoid suture. **Conclusions:** Cranial suture can be used as a tool for age estimation through usage of CT imaging both ectocranially and endocranially but with one decade interval error with no differences between males and females.

Key words

Suture; cranial; coronal, sagittal, lambdoid; suture closure; CT; age estimation

Introduction

Age estimation is a very important step for identification of unknown deceased being the integral part of one's biological profile. Although the majority of forensic age estimation cases are related to adolescents and early adults, nowadays cases of the geriatric population are also steadily increasing (Sittiporn et al., 2020).

Accurate age estimation in elderly people is essential in legal, medical, social and administrative matters i.e. retirement from service, pension settlement, senior citizen benefits, potency certification and relaxation in imprisonment on the grounds of old age of a prisoner (Ishita et al., 2022).

The error of age estimation increases with Age. Accurate estimation of adult age continues to be one of the most challenging tasks for forensic practitioners (Fan et al., 2020).

Usually the age estimation up to 25 years depends on physical examination, appearance of secondary sexual characters, data from dental eruption, and maturity of bones, appearance and fusion of ossification centers. After 25 years of age, it is associated with high percentage of deviation. It depends on associated aging changes in hair, eyes, and teeth (Anmol, 2019). Other scientific methods like tooth microscopy, study of union of parts of the sternum, pubic symphysis, auricular surface, lipping of

joints and closure of cranial sutures are considered for age estimation of the individual (Shaikh et al., 2017).

Since the development of CT, adults can have their full suture cross-section seen without being invaded (Chiba et al., 2013; Harth et al., 2009, 2010; Obert et al., 2010). A more thorough examination of suture closure may reveal more age-related alterations in comparison to the observation of superficial changes.

The use of multi-slice CT (MSCT) provides data that is consistent with measurements derived through using caliper in estimation of dry skull diameters (Abo El-Atta et al., 2020).

Aim of the Study

This study aimed to correlate the relationship between age and closure of cranial sutures and to estimate average age of closure of each suture (coronal, sagittal, and lambdoid) using CT imaging on a sample of Egyptian population.

Materials and Methods

Type of Study: Retro-spective cross-sectional study.

- Study Setting: The study was conducted in archive of Radiology department-Ain Shams University Hospitals in Cairo, Egypt.
- Study Population: 100 CT films of Egyptians divided into 5 age groups; group 1 (20-30 yrs), group 2 (>30-

40 yrs), group 3 (>40-50 yrs), group 4 (>50-60 yrs), and group 5 (> 60 yrs) as shown in table (1).

- Selection criteria for the study sample
1. Inclusion criteria
 - Availability of case records (age confirmation, date of imaging).
 - Case records of Egyptians of age group equal or more than 20 years old.
 - CT with adequate quality without any distortions.
 2. Exclusion criteria

Case records suffering from any of the subsequent problems were not accepted:

1. History of bone diseases, stunted growth or nutritional deficiency.
2. Skeletal malformation or deformity.
3. History of endocranial disorder.
4. Old healed cranial fracture.
5. CT imaging that shows fracture lesions or cranial bone anomalies.
6. Images of low or inadequate quality.
7. Unknown, unclaimed bodies where exact age cannot be confirmed.

Study tools:

Around 200 to 250 images were observed of which few images showing fusion, non-fusion or partial fusions were saved. On the whole suture 1mm cuts were taken in order to know the stage of fusion accurately. Window width was set around 1500 & Window length was set around 450. Field of vision was kept around 240 mm. Axial, coronal & sagittal sections were taken on CT scan at different levels on bone window of skull sutures.

Images were saved in all cases. The coronal suture was studied in three parts; C1: Pars bregmatica (i.e first part), C2: Pars complicate (i.e second part) and C3: Pars pterica (i.e third part).

Sagittal suture was studied in four parts; S1: Pars bregmatica (i.e. first part), S2: Pars verticis (i.e second part), S3: Pars obelica (i.e third part) and S4: Pars lambdicia (i.e fourth part).

Lambdoid suture has been divided into three parts from medial to lateral; L1: Pars lambdicia (i.e first part), L2: Pars intermedia (i.e second part) and L3: Pars asterica (i.e. third part) as shown in figure (1) (Chiba et al., 2013).

- Scale for closure:

Frederic rating scale

0 = patent

1 = less than half closed

2 = half closed

3 = more than half closed (almost complete closure)

4 = totally closed

(As seen in figures [2-6])

Ethical considerations:

This study was conducted after getting approval of the ethical committee of Faculty of Medicine, Ain Shams University, FMASU MS 455/2022.

Results

Table (1) shows age and gender distribution of the included 100 CT cases aged from 20 years and older.

Studied cases were divided equally into 5 groups according to the age; group (1) 20 - 30 years (20%), group (2) >30 - 40 years (20%), group (3) >40 - 50 years (20%), group (4) >50 - 60 years (20%), and group (5) >60. Females and males were equally represented.

The current study using Spearman correlation test between age and cranial sutures revealed a statistically significant positive correlation in the form of P value which indicates the statistical significance and rho value which indicates the type of correlation proving that cranial sutures are positively correlated with age with high statistical significance except for third part of coronal suture (C3) ectocranially and fourth part of sagittal suture (S4) endocranially as detailed in table (2).

Regarding the sagittal suture it starts at 49.19 ± 12.83 for endocranial surface and 42.9 ± 9.92 for ectocranial surface and ends at 49.87 ± 13.07 for endocranial surface and 50.39 ± 13.82 for ectocranial surface. For the coronal suture its closure starts at 45.23 ± 10.18 and 45.64 ± 12.12 for endocranial and ectocranial closure respectively and complete closure is found to be 49.6 ± 13.32 and 50.99 ± 13.29 for endocranial and ectocranial respectively; For While reviewing the lambdoid suture the mean age with SD in years for endocranial and ectocranial surfaces respectively is 47.24 ± 12.53 and 51.71 ± 12.99 and ends at 53.28 ± 13.88 and 55.09 ± 12.45 for endocranial and ectocranial surfaces respectively as shown in table (3) and Table (4).

Regarding closure sequence in the current study we observed that sagittal suture closes earlier and begins closure first through its second part (S2) at around 38.82 ± 11.62 followed by coronal sutures with the second part (C2) is the first to start closure with mean age of 43.29 ± 16.58 and then lambdoid suture.

All regression parameters exhibit statistical significance, emphasizing the importance of certain suture parts—Coronal 2_ecto, Sagittal1_endo, Lambdoid 1_ecto, Lambdoid2_endo, and Lambdoid 2_ecto as seen in figure (7).

The estimation of age from cranial suture closure, while feasible, carries an average error within one age group. The equation for this estimation is as follows:

$$1.45 [0.6 * Sen1 + 0.65 * Len2 + 0.28 * Cec2 + 0.35 Lec1 - 0.55 * Lec2].$$

Here, Sen1 corresponds to S1 endocranially, Len2 to L2 endocranially, Cec2 to C2 ectocranially, Lec1 to L1 ectocranially, and Lec2 to L2 ectocranially.

Table (1) shows age and gender distribution of the included 100 CT cases.

| | | No. | % |
|--------|-------------------------|-----|---------|
| Age | Group 1 (20 - 30 yrs) | 20 | 20% |
| | Group 2 (> 30 - 40 yrs) | 20 | 20% |
| | Group 3 (> 40 - 50 yrs) | 20 | 20% |
| | Group 4 (> 50 - 60 yrs) | 20 | 20% |
| | Group 5 (> 60 yrs) | 20 | 20% |
| Gender | Females | 50 | 50% |
| | Males | 50 | 50% |
| Total | | 100 | 100.00% |

Table (2) shows spearman correlations between age and closure of cranial suture parts.

| Suture part | AGE | | | | | | |
|-------------|---------|-------------|-----|-------|-------------|-----------|-----|
| | P value | Ectocranial | | | Endocranial | | |
| | | Rho value | Sig | | P value | Rho value | Sig |
| Coronal 1 | 0.001 | 0.38 | HS | 0.001 | 0.45 | HS | |
| Coronal 2 | 0.001 | 0.42 | HS | 0.001 | 0.34 | HS | |
| Coronal 3 | 0.29 | 0.11 | NS | 0.04 | 0.20 | HS | |
| Sagittal 1 | 0.001 | 0.44 | HS | 0.001 | 0.53 | HS | |
| Sagittal 2 | 0.004 | 0.28 | HS | 0.002 | 0.30 | HS | |
| Sagittal 3 | 0.01 | 0.24 | HS | 0.01 | 0.25 | HS | |
| Sagittal 4 | 0.03 | 0.21 | HS | 0.1 | 0.15 | NS | |
| Lambdoid 1 | 0.001 | 0.42 | HS | 0.004 | 0.28 | HS | |
| Lambdoid 2 | 0.001 | 0.41 | HS | 0.001 | 0.55 | HS | |
| Lambdoid 3 | 0.001 | 0.42 | HS | 0.001 | 0.45 | HS | |

P>0.05: Non-significant, P< 0.05: Significant, Rho< (0) - (-1): negative correlation, rho> (0)-(1): positive correlation

Table (3) presents the mean age and standard deviation at the initiation of closure for the segmented parts of the studied sutures, both ectocranially and endocranially.

| | Coronal | Sagittal | Lambdoid |
|----------------------------|-------------|-------------|-------------|
| Ectocranial (Age in years) | 45.64±12.12 | 42.9±9.92 | 51.71±12.99 |
| Endocranial (Age in years) | 45.23±10.18 | 49.19±12.83 | 47.24±12.53 |

Table (4) displays the mean ages of end or complete closure of the three studied sutures.

| | Coronal | Sagittal | Lambdoid |
|----------------------------|--------------|-------------|-------------|
| Ectocranial (Age in years) | 50.99 ±13.29 | 50.39±13.82 | 55.09±12.45 |
| Endocranial (Age in years) | 49.6±13.32 | 49.87±13.07 | 53.28±13.88 |

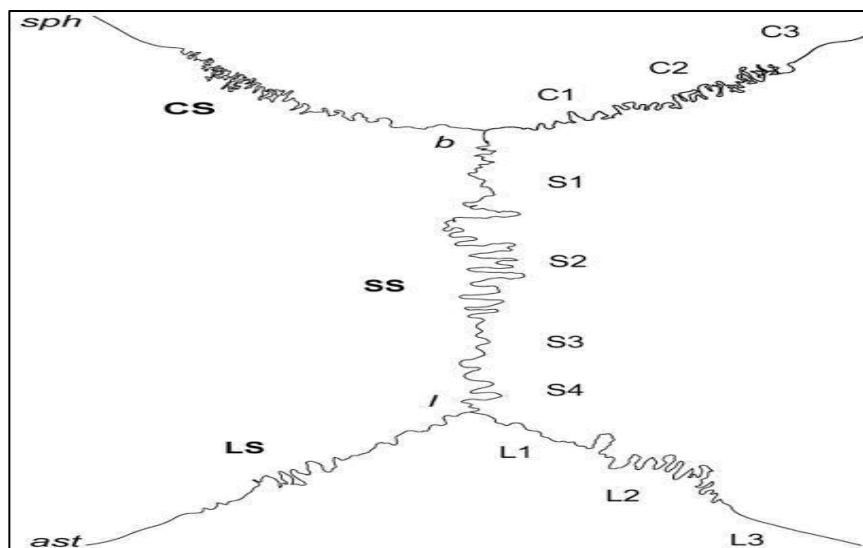


Figure (1): Anatomical parts of coronal, sagittal and lambdoid sutures (Chiba et al., 2013)

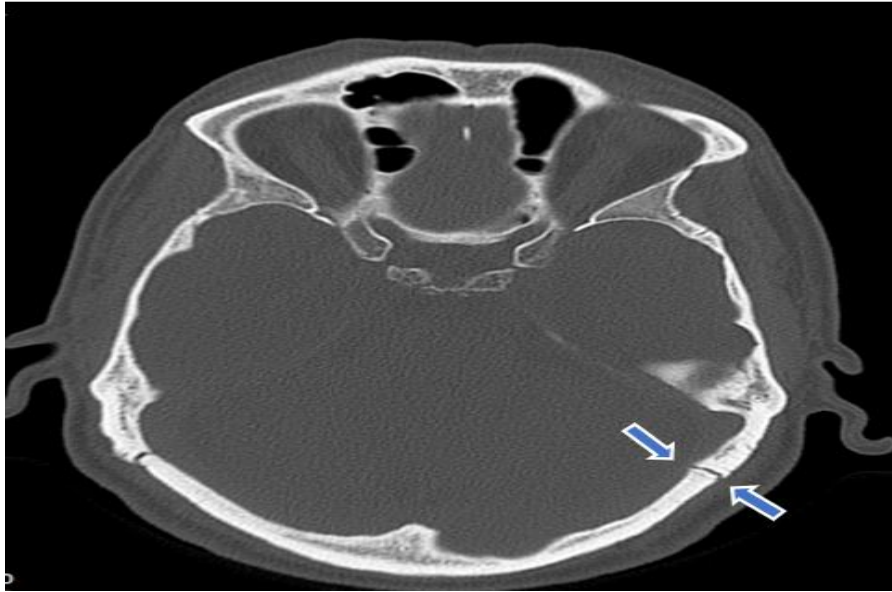


Figure (2) showing stage (0) of Frederic scale with arrows pointing at lambdoid suture.

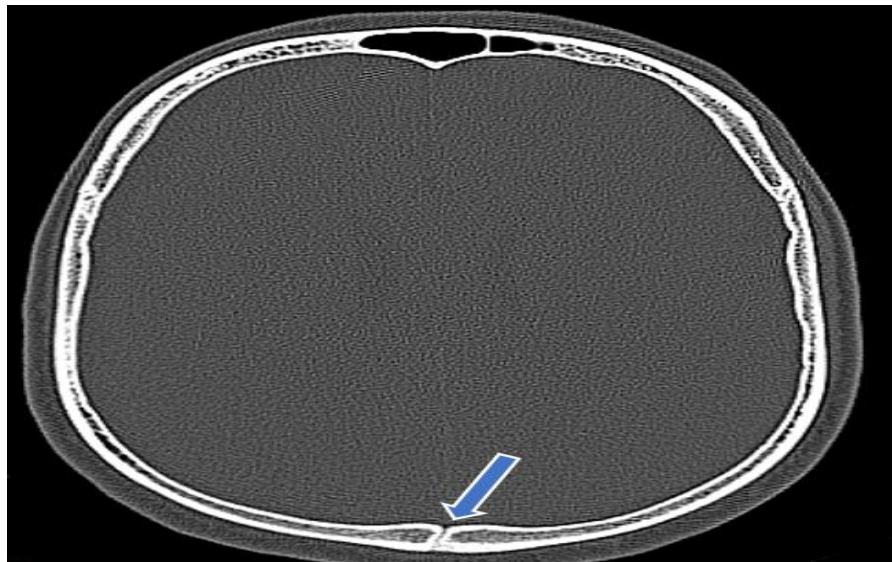


Figure (3) shows stage (1) of Frederic rating scale with an arrow pointing at sagittal suture.



Figure (4) showing Stage (2) of Frederic rating scale with the arrow pointing at coronal suture

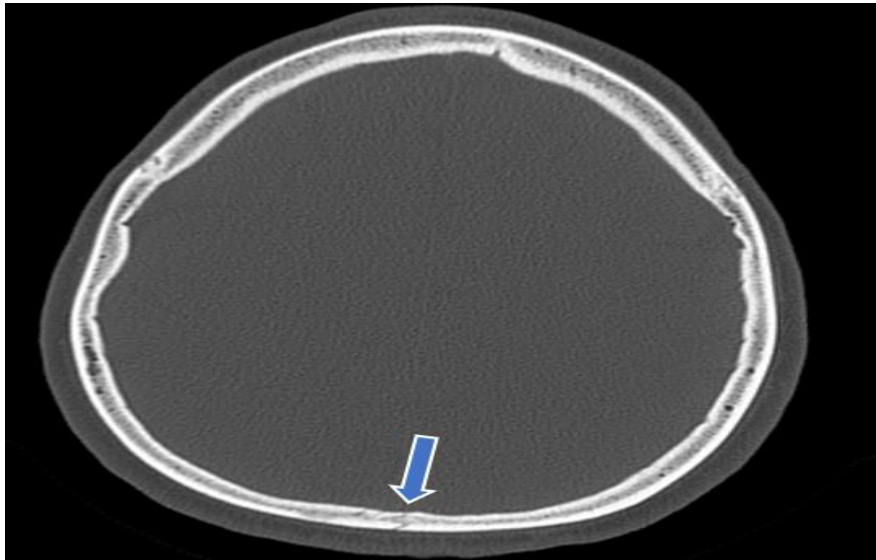


Figure (5) showing Stage (3) of Frederic rating scale with arrow pointing at sagittal suture.

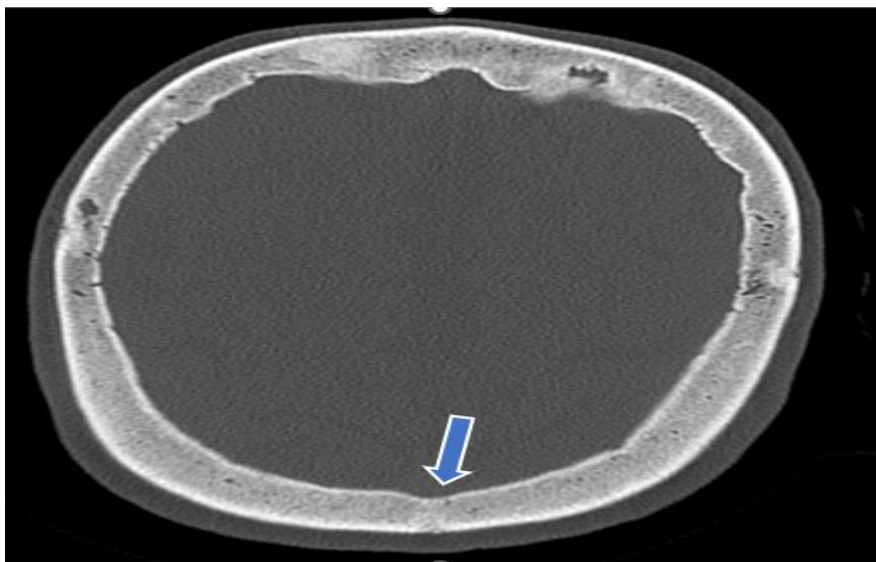


Figure (6) showing Stage (4) of Frederic rating scale with arrow pointing at sagittal suture.

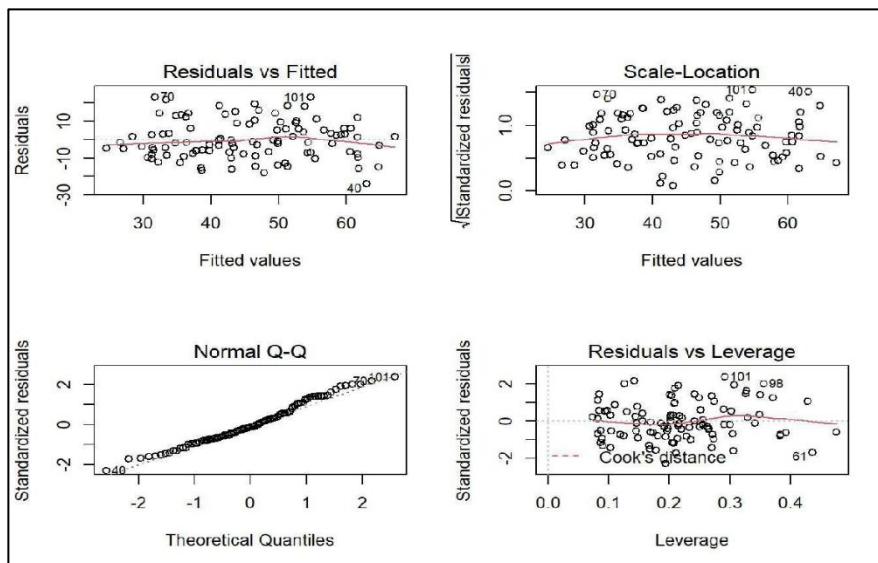


Figure (7) portrays a scatter plot illustrating linear regression models for age estimation utilizing cranial sutures.

Discussion

Age estimation is one of the main challenges in forensic sciences. Determining a victim's or suspect's age accurately can help investigators focus their search and move closer to a precise conclusion (Fan et al., 2020).

Cranial suture closure is one of the most commonly used age estimating methods for decades. Despite its great variability and controversy in age estimation, it may provide the key to forensic investigations serving identification and crime as the best preserved part of the body is the skull (Marta & Zniak., 2021).

Sagittal, lambdoid, and coronal sutures have been shown in several studies to be potential indicators for adult age estimation (Singh et al., 2004, Gaur et al., 2007; Parmar & Rathod, 2012). Cranial sutures should be used in conjunction with techniques, according to some authors (Boyd et al., 2015; Chiba et al., 2013; Harth et al., 2010; Nikolova et al., 2019).

The present study revealed that cranial sutures are positively correlated with age with very strong statistical significance except for third part of coronal suture (C3) ectocranially and fourth part of sagittal suture (S4) endocranially.

These results are consistent with findings of Harth et al. (2009) where flat-panel CT was used. Similarly; Chiba et al. (2013) who conducted a study on 125 multi-detector CT images of the sagittal suture who reported that according to the analysis done by Pearson test there is statistically significant positive correlation between age estimation and cranial sutures. It is also compatible with Fan et al. (2020); Chawla et al. (2023) and also Akbar et al. (2023) who utilized three dimensional CT scan and observed a statistically significant correlation between chronological age and cranial suture obliteration.

Upon comparing our results with results from same ethnicity we found that similar findings published by Manal et al. (2020) who conducted their study on sixty Egyptian people. The fusion status of cranial sutures was evaluated ectocranially at ten anatomical landmarks, Correlations indicating a positive relationship between age and the closure of sutures were identified by their study.

Contrary the findings of Obert et al. (2010) reported that suture closure is neither correlated nor beneficial in age estimation for both genders; Kumar et al. (2012), Sahni et al. (2005), Wolff et al. (2012), and also Marta & Zniak. (2021) reported that there is no statistically significant association between an individual's age and the level of suture closure, these differences possibly due to the various methodology and ethnicities among the studies.

Regarding the sagittal suture it starts at 49.19 ± 12.83 for endocranial surface and 42.9 ± 9.92 for ectocranial surface and ends at 49.87 ± 13.07 for endocranial surface and 50.39 ± 13.82 for ectocranial surface. For the coronal suture its closure starts at 45.23 ± 10.18 and 45.64 ± 12.12 for endocranial and ectocranial closure respectively and complete closure is found to be 49.6 ± 13.32 and 50.99 ± 13.29 for endocranial and ectocranial respectively; For While

reviewing the lambdoid suture the mean age with SD in years for endocranial and ectocranial surfaces respectively is 47.24 ± 12.53 and 51.71 ± 12.99 and ends at 53.28 ± 13.88 and 55.09 ± 12.45 for endocranial and ectocranial surfaces respectively.

Singh et al. (2004); observed that closure is obtained at 45-50 yrs of age for coronal suture and 45-50 yrs of age for lambdoid suture which is consistent with our finding.

Masih et al. (2014); also observed in their study that coronal suture closure in either sex was completed at the age of 46-50 yrs; sagittal suture completion of obliteration took place at the age of 51-55 yrs.

Sunira et al. (2015); made their study on a total sample of randomly selected 85 cases by applying a modified reverse panoramic radiograph on lambdoid suture for age estimation they applied Fredric rating scale and found that most of the lambdoid sutures attained closure by mean age of 49 and complete closure by mean age of 66 years which is similar to the present study and is also supported by the observation done by Parikh, (1990), Singh et al., (2014), Dikshit. (2013), Karmakar, (2010), and Mukherjee, (2011) on Indian population where lambdoid suture attains closure between 45-50 yrs. Nandy, (2007) and Vij, (2011) also observed that complete closure of lambdoid suture is achieved by the age of 55 years.

Anmol. (2019); Studied 95 adults who had undergone a CT scan of the skull found the mean age at which each suture complete closure was as follows: sagittal suture at 55-65 yrs, coronal suture at 55-60 yrs, and lambdoid suture at 65-70 yrs.

Lambdoid suture in the age group of 20-80 years was studied in roentgenograms (skull radiography) by Ishita et al. (2022). The lambdoid suture begins to fuse in the top half by 34 yrs of age, and in the lower half, it completely fuses by 44 yrs of age, according to their research.

Marta & Zniak. (2021); studied complete closure of sagittal suture. A mean age of 50.48 years was identified.

As regard the Egyptian study conducted by Manal et al. (2020), their results were consistent with the findings of the present study. Their study found that; in the sagittal suture, males exhibited a mean age of start of closure of 34.00 ± 7.54 , while females showed 38.17 ± 12.09 and end of closure at around 51.50 ± 18.53 for males and 51.58 ± 11.95 for females. For the coronal suture, combining the right and left limbs, males demonstrated a mean closure age of 37.75 ± 12.28 , and females 42.43 ± 10.39 while end of closure occurs at 51.96 ± 15.58 and 51.1 ± 13.55 . Lastly, in the lambdoid suture, combining both limbs, males had a mean age of closure of 29.25 ± 7.63 , compared to females with 34.11 ± 11.97 and ends at 59.80 ± 8.92 and 54.0 ± 12.00 for males and females respectively.

However, Kumar et al. (2012), found that endocranial fusion of coronal suture was observed as early as 20-29 years, Fusion of sagittal suture, on endocranial surface, starts towards the end of 21-30, lambdoid suture fusion starts at the age of 21-30 years.

In contrast Fan et al. (2020), study showed that the sutures attained complete closure only over the age of 72 years. Different ethnic origins and observation techniques for cranial suture closure could be the causes of the diversity in cranial suture closure as stages of non-fusion and incomplete fusion were not observed by their study.

In the current study we observed that sagittal suture is the first suture to close, it begins closure first through its second part (S2) at around 38.82 ± 11.62 followed by coronal sutures with the second part (C2) is the first to start closure with mean age of 43.29 ± 16.58 and then lambdoid suture.

Similarly, Anmol. (2019) and Chawla et al. (2023); observed that sagittal suture fuses early followed by coronal sutures and then lambdoid sutures.

These results are compatible also with studies by Sabini & Elkowitz, (2006), Murlimanju et al. (2011) and Kampan et al. (2014) who reported that the lambdoid suture was the last suture of the cranial vault to close.

In contrast to the current study is the study by Ullas. (2009) who concluded that endocranially coronal suture closes first then sagittal suture and finally lambdoid suture. In case of ectocranial closure, sagittal suture closes earlier followed by lambdoid suture and lastly coronal suture.

Conclusion and Recommendations

Even though suture study has certain subjective components, suture closure state adds more information to age range estimation, particularly in older adults where other methods become less useful, so the present study concluded that, cranial sutures could be a measure for age estimation. Further studies regarding sample size are recommended.

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تقدير العمر عن طريق معرفة التحام بعض الدروز القحفية (الإكليلي، السهمي واللامبي) على جزء من المصريين بواسطة الأشعة المقطعية: دراسة مرجعية

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الملخص العربي

التقدير الدقيق للعمر أمر ضروري في أنثروبولوجيا الطب الشرعي، وعلم الآثار البيولوجية، والتحقيقات الطبية القانونية. أتاحت التطورات الحديثة في التصوير المقطعي المحوسب فحصاً تفصيلياً لدروز الجمجمة، مما يوفر رؤى قيمة. **الهدف:** تهدف هذه الدراسة إلى ربط العلاقة بين العمر ودروز الجمجمة وتقدير متوسط عمر إغلاق كل درز (الإكليلي، السهمي، اللامبي) باستخدام التصوير المقطعي على عينة من المصريين. **طرق البحث:** تم تضمين إجمالي 100 شخص في الدراسة، بعمر 20 سنة وما فوق، وتم تقسيمهم بالتساوي إلى خمس مجموعات بفاصل عمري 10 سنوات؛ المجموعة 1 (20-30)، المجموعة 2 (<30-40)، المجموعة 3 (<40-50)، المجموعة 4 (<50-60) والمجموعة 5 (<60). تم تقييم إغلاق الدروز وفقاً لمقياس تقييم فريدريك للتصوير المقطعي. وتم تحليل البيانات المكتسبة إحصائياً. **النتائج:** كشفت الدراسة الحالية عن وجود علاقة إيجابية بين العمر ودروز الجمجمة، كما لاحظنا أن الدرز السهمي ينغلق مبكراً حيث يبدأ الإغلاق أولاً من خلال جزئه الثاني (2S) عند حوالي 11.62 ± 38.82 يليه الدرز الإكليلي مع الجزء الثاني منه (C2) هو أول من بدأ الإغلاق بمتوسط عمر 16.58 ± 43.29 ثم الدرز اللامبي. **الاستنتاجات:** يمكن استخدام دروز الجمجمة كأداة لتقدير العمر من خلال استخدام التصوير المقطعي المحوسب خارج القحف وداخل القحف، ولكن مع وجود خطأ بفاصل زمني قدره عقد واحد مع عدم وجود فروق بين الذكور والإناث.

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