ANIL AGGRAWAL'S
Internet Journal of
Forensic Medicine and Toxicology
The world's first online journal devoted entirely to forensic medicine and toxicology · Published 1 January and 1 July

VOL. 10, NO. 2 · JULY – DECEMBER 2009
Downloaded from www.anilaggrawal.com · ISSN 0972-8074 (Online) · https://www.anilaggrawal.com/ij/vol_010_no_002/others/thesis/ullas.html

Macroscopic study of cranial suture closure at autopsy for estimation of age

DEDICATION

This thesis is most respectfully dedicated to my brother Dr. Umesh Kumar Shetty. Whatever I am today is because of him.

DECLARATION

I, Dr. Ullasa shetty declare to the best of my knowledge, that the contents of the thesis have not been submitted earlier in candidature for any degree.

I, hereby give consent for availability of my thesis for photocopying and interlibrary loan to institutions.

DR. ULLASA SHETTY

CERTIFICATE

This is to certify that this thesis entitled **"MACROSCOPIC STUDY OF CRANIAL**

SUTURE CLOSURE AT AUTOPSY FOR ESTIMATION OF AGE" *is* the bonafide work of

Dr. Ullasa shetty conducted in the department of forensic Medicine, Maulana Azad

Medical College, New Delhi, under our guidance and supervision.

Supervisor

Dr. ANIL AGGRAWAL

PROFESSOR

Department of Forensic Medicine

Maulana Azad Medical College

And associated hospitals

New Delhi – 110002

Co-Supervisor

DR. S. K. KHANNA

DIRECTOR PROFESSOR

Department of Forensic Medicine Maulana Azad Medical College

And associated hospitals

New Delhi - 110002

ACKNOWLEDGEMENT

I would like to express heart felt gratitude to my esteemed supervisor, Dr.

Anil Aggrawal, Professor, Department of Forensic Medicine, Maulana Azad Medical College, New Delhi for his invaluable guidance and constructive criticism.

I express sincere gratitude to my Co-Supervisor Dr. S.K.Khanna, Director Professor and HOD, Department of Forensic Medicine, Maulana Azad Medical College, New Delhi who provided guidance and support all through the study.

I am especially thankful to Dr. Anil Kumar Mittal Professor, Dr.Bhim Singh Asst.professor, Dr. Sreenivas, Asst.Professor, Dr.Upender Kishore

Asst.Professor for their keen interest and encouragement. I am also thankful to my colleagues especially, Dr. Vijay Dhankar, who helped me with his expertise in software application and Dr. Kulbhushan for his cooperation.

Their moral support and encouraging words have helped me sail smoothly through this period. I am also thankful to Dr. Arvind(UCMS), Dr.Thejaswi (LHMC), Dr. Sunay (AIIMS), Dr.Somnath Dutta and Dr. Rajkumar (MAMC) for their kind help and support. I am also thankful to all the mortuary staff.

I am thankful to Dr. Jugal Kishore, Professor of Community Medicine at the Maulana Azad Medical College, who spent his invaluable time with me and explained many difficult concepts of statistics to me, which I incorporated in the thesis.

I would like to pay my respects to all departed souls on whose bodies the study was conducted.

I praise the Good almighty for helping me to complete this study successfully.

DR. ULLASA SHETTY

TABLE OF CONTENTS

TOPIC	PAGE NO.
1. Introduction	1 - 6
2. Review of literature	7 - 36
3. Objectives of Research	37
4. Materials and Methods	38 - 41
5. Results	42 - 62
6. Discussion	63 - 69
7. Conclusion And Recommendations	70 - 73
8. Index of References	74 - 77
9. Appendix	
• List of abbreviations	
• Proforma	
• Master Chart	

INTRODUCTION

Identification is recognition of an individual by means of various physical features and biological parameters, which are unique to each individual. There are various established parameters for identification of an individual. These are external features (such as birth marks, scar, tattoo marks ,occupational marks, malformations), personal features (such as clothes, speech, habits, handwriting), assessment of age and sex, determination of race and stature, anthropometric measurements, finger prints and foot prints, DNA finger printing.[1,2,3]Question of identification arises in everyday medico legal practice both in civil and criminal cases.

Since the bone resists putrefaction and destruction by animals, they can lead to the reliable determination of age, sex, race, stature of the individual. Age being once of the cardinal parameter for establishing the identity, its estimation is of paramount importance and requires special attention in cases where bodies are found in decomposed, mutilated state or only fragmentary remains are discovered.

In adults mainly there are macro and microscopic methods of age estimation. The principal macroscopic changes are metamorphosis of pubic symphysis, closure of cranial sutures and degenerative changes in vertebral bodies and joints.

The use of cranial sutures for age estimation has always been a matter of considerable debate and its reliability within the parameter has not been demonstrated conclusively by various researchers. Only handful of studies has been conducted in India, and data on

heterogeneous population of Delhi region is virtually non-existent. It may not be difficult to determine the age of the person with certain degree of accuracy from birth onwards as far as up to 25 years.

The determination of age is needed for employment, marriage, majority, management of property, voting right, competency as witness and testamentary capacity. The significance of determination of the age is most important in the criminal cases, such as rape, infanticide, kidnapping, prostitution, juvenile delinquency and criminal responsibility.

Reasonably a correct estimation of age in elderly people is essential in legal, medical, social and administrative matters i.e. to fixing of age for regularization of employment, superannuation, pension settlements, senior citizen benefits, old age and good behavior of the prisoner.

The assessment of age is done by anthropologist, archeologist, anatomist and persons engaged in medico legal works. Among all these, the work of Forensic expert requires special attention because his findings are directly related to the administration of the law and his conclusions are debated in court of law. The needs of determination of age vary from intrauterine life to old age for different purposes. Sometimes even when the age of person is known by the horoscope, hospital records and birth certificate, but still its scientific confirmation is required by court of law and certain administrative departments. In India and many other countries the task of scientific confirmation of disputed age issues of civil and criminal nature is the domain of forensic expert.

The scientific estimation of age is not an easy task especially in adult age group. Usually the age estimation up to 25 years is done by physical examination, appearance of secondary sexual characters, data from dental eruption, and maturity of bones, appearance and fusion of various ossification centers. However these data to some extent are influenced by heredity, climate, race, diet, hormone level, disease process etc.

After 25 years of age, other scientific methods like tooth microscopy, Gustafsons method (applicable to dead persons only), study of union of parts of sternum, lipping of joints and closure of cranial sutures are considered for age estimation of the individual.

Sutures are analogous to the epiphysio-diaphysis plane, in which both are loci of growth and have a sequence of time of closure.

The texture of a young adult skull is smooth on both the inner and outer surfaces (Krogman 1962:88). Krogman (1962:88) provides the following cranial morphological age sequence: 1) from the age of 25, muscular markings become increasingly evident, especially on the temporal, occipital and on the lateral side of the mandible; 2) around 35 to 45 years, the surface begins to assume a matted, granular appearance; 3) on the inside of the skull, the Pacchionian depressions, both deepen and occur with much more frequency; 4) after the age of 50, the diploe become less vascular channeled and there is an increasing replacement by bone. However, there is no consistent age change in the thickness of the cranial bones (ibid.).

The bones of the skull have two layers, the tabula interna and externa, which are separated by a vascular spongy bone space (diplöe) (Krogman 1962:85). These bones are separated by sutures which, in a series, are analogous to the epiphyseo-diaphyseal

planes that in both are loci of growth, and that both have a sequence of timing and union (Krogman 1962:76). Just as the epiphyseo-diaphyseal union most frequently begins centrally and proceeds peripherally, so does suture closure begin endocranially and proceed ectocranially (ibid.). In many cases, complete closure will obliterate any signs of the cranial sutures (Krogman 1962:85).

There is a difference however; the epiphyseal union is always complete in normal closures (with the possible exception of the ramal epiphysis of the ischium) whereas suture closure may be incomplete in normal, healthy individuals (Krogman 1962:76).

The metopic suture, which is present at birth between the right and left halves of the frontal bone, usually closes around the age of two (Woo 1949:216). However, in some individuals, it is persistent into later adult life. Metopism is more frequent among white? And Mongoloid? Populations (roughly 10% occurrence) compared to a 2% occurrence among Negroid? (Woo 1949:224).

Forensic anthropologists are frequently called upon to derive as much information as possible from very limited or poorly preserved remains. The method of determining age by cranial suture closure has always been more generally used, due not only to the greater interest in the skull, but because the cranium is frequently the best preserved portion of the recovered skeleton (Brooks 1955:567-568). As such, osteologists have developed numerous techniques which, when applied in concert, increase the accuracy of identification (Lovejoy et. al. 1985:2).

Use of suture closure as an age estimate is predicated upon the hypothesis that suture closure is part of the aging process. However, when suture closure patterns were first studied at the beginning of this century, there were two schools of thought (British and Italian) on this issue (Hershkovitz et. al. 1997:393). The British school maintained that sutural ossification and cranial immobility were normal conditions, whereas the Italian school maintained that they were pathologic in mature human adults (ibid.). In time, probably due to the increasing prominence of the English language in the scientific literature, the British approach toward suture closure became the dominant model in physical anthropology (without actually testing that hypothesis) (Hershkovitz et. al.

1997:394).

The work of Todd during the 1920s provided anthropologists with a framework for estimating age of death from both the pubic symphysis and the cranial sutures (Todd 1924, 1925a, 1925b, 1925c). The use of cranial sutures in estimating (adult) age at death came under criticism during the 1950s. These critiques focused upon Todds methodologies, conclusions and the error rates of the method itself (Singer 1953; Brooks 1955; Powers 1962; Krogman 1962). It was noted that the ages obtained from cranial suture closure either produced skewed mortality rates or did not correlate with known age of death (Singer 1953; Brooks 1955). During the 1970s through to the 1990s, several researchers re-examined the use of cranial sutures as a means of determining age at death (Johnson 1976; Meindl and Lovejoy 1985; Masset 1989; Key et. al. 1994; Nawrocki 1998). According to Meindl and Lovejoy (1985:57), this period of investigative research was characterized by a trend in skeletal biology? During which it was hoped that one or two highly reliable age indicators would be isolated and perfected?

Despite being used since the 16th century, the use of cranial sutures for determining age at death is regarded by many forensic anthropologists as an overall weak methodology (Meindl and Lovejoy 1985:57). According to Hershkovitz et. al. (1997:395), standard aging methods based on suture closure make use of two arbitrary assumptions: 1) that the different degree of suture closure (usually four stages) represents a normal progressive process, and 2) that different ontogenetic processes operate in different segments of the same suture. Hershkovitz et. al. (1997:395) believe that these assumptions have no factual basis, and that their application is very subjective for the following reasons: the division between segments of the same suture are not clear cut in many skulls, and more than 20% of skulls do not follow the classic Pattern of sutural segmentation (ibid).

REVIEW OF LITERATURE

A number of studies have been conducted abroad on the closure of the cranial sutures as a sign of ageing namely Dwight (1890), Frederic (1905), Person and Box(1905),Todd and Lyon (1924-25)

Cattaneo,L(1937),Harlick(1939),Franchini (1946)

Singer(1953),Mckern and Stewart (1957).

In India the available study on the subject are Yadav S.S and Puri P.R (1971),Patil T.L (1981),Bhagwat S.S (1983) and Chandrashekharan P.(1985), Dr.Bimal

Chandra(1984,Delhi), Vyas P C (1996),Moondra A.K (2000),Rajesh kumar verma(2002), Dr.Pradeep singh(2004,Patiala), Daisy Sahni(2004, Chandigrh).

The bones of skull are separated by sutures ,which in a sense are analogues of epiphysio-diaphysial planes in which there are loci of growth and they have a sequence and timing of union (Krogman,W.M 1978).the word suture is derived from Latin sutura ,which means seam li

The sutures on the skull are seam like lines of junction in which the connective tissue is a fibrous membrane, or synchondroses in which the bones are united by a bar of syarthrosis characterized by absence of joint cavity and a paucity of motion with advancing age they tend to become obliterated although this is by no means uniform.

Historical Research (A. D. 100-1890)

Todd and Lyon (1924:327) present the following historical account of cranial sutures.

Cranial sutures were viewed as controlling both the growth of the brain and, therefore, the shape of the skull. Although classical authors, like Hippocrates, Aristotle and Galen, had observed that some human crania exhibit open sutures, whereas others are almost or entirely devoid of them, the fact that union occurred during life did not appear in the anatomic literature until the works of Gabriele Fallappia (1523-1562), in the middle of the 16th century (Todd and Lyon 1924:327).

Additionally, it was assumed that the Condition of the sutures were indicative of racial background (Todd and Lyon 1924:328). For example, in the 1st century A. D., Celsus, in his compendium of medical learning, stated that crania devoid of sutures occur more readily in warm climates [in reference to Ethiopians] (ibid.). Fallappia, best known for his

identification of the fallopian tubes, was encouraged by his teacher, Andreas Vesalius (1514-1564), to challenge the classical view that sutures had a close relation with skull morphology (ibid.). One hundred years later, other anatomists had come to agree that this relationship could only be found in rare instances (Todd and Lyon 1924:327).

In 1641, Thomas Bartholin (1616-1680) proposed the following uses for cranial sutures (Todd and Lyon 1924:326): 1) to permit the free transpiration of the vapours in the brain; 2) for the attachment and suspension of the dura matter; 3) for the transmission of fibers of the dura through to the pericranium; 4) for the transmission, in both directions, of vessels carrying nourishment and life to the parts; 5) to diminish the likelihood of fracture of the bones of the skull [Interestingly, Hershkovitz et. al.

(1997:397) have once again suggested that open sutures may increase skull efficiency in absorbing related mechanical stresses]; and 6) to permit the penetration of applications from the exterior.

Bartholin asserted that the number and location of the sutures was the same in males and females, and were rarely changed by the shape of the cranium (Todd and Lyon 1924:327). It was proposed that these cranial deformations occurred during fetal development or at birth (ibid.). In the 18th century, anatomists emphasized the analogy between sutural membranes and the diaphyso-epiphseal plane (Todd and Lyon 1924:328). The Hippocratic idea of the relationship between cranial form and suture condition was revived in the 19th century. Since the middle of the 19th century, the growth of the brain has been viewed as a cause, rather than effect, of suture closure (ibid.).

During the 19th century, it was observed that cranial union first occurs in the sagittal suture, and that it occurred earlier within the cranium than upon the exterior (Todd and Lyon 1924:328). In 1856, the anatomist Louis Pierre Gratiolet (1815-1865) proposed a sequence for suture closure and stated that union occurred earlier in Negroes? It should be noted that Gratiolet made this distinction in order of cranial closure between higher and lower races of mankind?, with Negroid races belonging to the lower group (Todd and Lyon 1924:342). Gratiolet, observed that ectocranial suture closure progressed sequentially (Todd and Lyon 1924:353): sagittal, lambdoid, then coronal.

Other anatomists began to try to establish an age related sequence for cranial suture closure. For example, in 1861, the physician Paul Broca observed visible sutures in males over the age of 50, and developed a 4 point rating system for cranial suture closure (Todd and Lyon 1924:353). Over time, it came to be accepted that, in the white stock union began between the ages of 40 and 45 (ibid.). However, in 1869, F. Pommerol noted that the period of union, for each suture, varied across individuals but followed the general pattern (Todd and Lyon 1924:328-329). Pommerol identified the following sequence (ibid.): 1) individuals under 35 years of age had open cranial sutures; 2) around 40 years, the sagittal suture begins to close; 3) around 50 years, the coronal suture begins to close; and 4) by 65 years or more, the temporal suture has finished closing.

In 1885, F. C. Ribbé examined 50 skulls of known age 40 of which were of white stock , the other 10 presumably non-white (Todd and Lyon 1924:329). He found that the earliest occurrence of cranial suture union was at 21 years and the latest at 55 years.

Taking the mean, Ribbé concluded that closure commenced between the ages of 40 and 45, with a standard deviation of 15 to 20 years (ibid.). He stated that ectocranially, sagittal and lambdoid sutures closed before the coronal (Todd and Lyon 1924:355).

In 1888, Schmidt proposed that the basal suture untied between 18 to 21 years, but possibly between 25 and 40 years, and was complete between 40 and 60 years (Krogman 1962:77). In 1890, T. Dwight proposed that before the age of 30, all of the cranial sutures were open (ibid.). Krogman (1962:77) states that Dwight also observed that suture closure began endocranially and occurred later in females than in males (Todd and Lyon 1924:329). Dwight concluded that closure was irregular and, as such, not of value as an indicator of age (Krogman 1962:77). However, his samples consisted of street urchins of indeterminate ages and he did not indicate whether his conclusions referred to internal or external suture closures (Todd and Lyon 1924:329).

Twentieth Century Research

Parsons and Box

In 1905, F. G. Parsons and C. R. Box examined the significance of internal suture closures using 82 male and female skulls of known age (Todd and Lyon 1924:329). They (Krogman 1962:78) concluded that: 1) closure rarely occurred in a healthy skull before the age of 30; 2) between 30 and 50 years of age there is a fair amount of endocranial closure in coronal and sagittal sutures; and 3) over 60, all endocranial sutures were obliterated. Parsons and Box also suggested that less serrated (simple) sutures closed before all other sutures, and that there were no differences in closure periods for the left or right side of the skull (ibid.). They proposed that the lambdoid was the last of the vault sutures to reach complete closure (Todd and Lyon 1924:355). Overall, they concluded that Dwight was justified in his assessment that cranial sutures closed later in females and that cranial sutures were not a good indicator of age (Todd and Lyon 1924:329; Krogman 1962:78).

Frederic

In 1906, J. Frederic examined 255 European and 119 non-European crania of known age (Todd and Lyon 1924:329). However, only 91 European and 13 non-European crania of both sexes were opened so that the internal surface could be examined (ibid.).

Following Broca, Frederic introduced his own rating scale of 0 to 4 (open, less than one half closed, half closed, more than one half closed, and totally closed) (Krogman 1962:77-78). Examining endocranial sutures, he found that the lambdoid closed after the sagittal and coronal (Todd and Lyon 1924:355). Frederic concluded that it was not possible to determine the age of a skull by the condition of suture union closure with any accuracy greater than +/- one decade (ibid.). However, he stated that suture closure occurred later in females, thus concurring with Dwight, Parsons and Box (Krogman 1962:78).

Bolk

In 1915, Louis Bolk calculated the absolute frequency of premature obliteration in 1820 European juvenile skulls, from which he (Bolk 1915:496) proposed the following terminology for suture

closure: precocious (closure before the age of seven) and premature (closure after the age of seven but before the 'normal' age of closure).

Todd and Lyon

The research of Todd and Lyon (1924, 1925a, 1925b, 1925c) provided the groundwork for all North American forensic and physical anthropological studies for the remainder of the 20th century. In 1924, Todd and Lyon proposed to "present the facts concerning suture closure and its relation to the racial form and individual contour of the brain case" (1924:326). The research by Todd and Lyon (1924, 1925a, 1925b, 1925c) was the first new attempt to estimate age using endo and ectocranial suture closure since Pommerol, Ribbe, Frederic, Parsons and Box, with the specific aim to create a precise numerical rating system for cranial closure (Krogman 1962:78). Todd and Lyon (1924:355) state that:

Until we gathered the accurately dated material in the Hamann Museum, no one possessed a sufficient collection of skulls of known age to justify the interpretation of suture closure upon its age relationship.

Todd and Lyon (1924, 1925a, 1925b, 1925c) tried to ensure that the skeletal material was large enough to justify it as a sample of the population under study. In addition to sex and race, verifiable age at death had to be known and the crania had to be cut, so that examination of the interior surface was possible. Todd and Lyon (1924:330) initially examined the crania of more than 1,000 individuals, from which those of which were of uncertain known age, and did not have a complete post cranial skeletal for comparative study were rejected. Of the original 1000 specimens, 514 crania of known age were examined (ibid.): 307 crania of white males, 58 white females, 120 Negro males, and 29 Negro females. From this initial sample, 40 white skulls (13.3%) and 41 (34.2%) were excluded as anomalous (Krogman 1962:79).

Todd and Lyon (1924, 1925a, 1925b, 1925c) provide detailed accounts explaining both which skulls (by catalogue number and age) were rejected, and pertinent cranial features which led to the rejection. Rejections were based upon: 1) whether or not the skull belonged to skeletons belonging to the symphyseal anthropoid strain (Todd and Lyon 1924:339-340):

It is characteristic of the anthropoid strain that the pubic age relationships fall nearer to those of the Giant Anthropoids, and there is a clear difference in age relationship of the skeleton between human beings according, as they exhibit the anthropoid strain or the regressive form of symphysis. In the first place, elimination based on the anthropoid strain in the pubic symphysis affects skeletons of the third decade.2) precocious union; 3) no endocranial closure of vault sutures; 4) evidence of dwarfism; and 5) no endocranial closure of any cranial sutures. As stated by Todd and Lyon (1924:348), they were confident in their rejections because they were able to examine the entire skeleton and they were cross referenced with legal documentation of age at death.

The age of the specimens ranged from 18 to 84 years (Todd and Lyon 1924:338). Todd and Lyon state that this relatively small sample size was statistically accurate, since the objective of the study was to determine the progress of cranial suture union (ibid.). They note that in certain instances, they observed that sutures seemed to fail to completely close (Todd and Lyon 1924:337). This condition was defined as 'lapsed union' of the

suture. They defined it as the incomplete union of the suture, characterized by a build up of bone tissue along the edges of the unclosed part (ibid.). Todd and Lyon (1924:337) classed incidents of lapsed union as closed, since a suture in this condition would be unlikely to close to any great extent.

Following the precedent set by anatomists of the seventeenth century, Todd and Lyon (1924:336) grouped the sutures in the following manner: vault [sagittal (and metopic), coronal and lambdoidal]; accessory [spheno-frontal and spheno-parietal]; and circum- meatal [spheno-occipital]. For later decades, they eliminated skulls which exhibited partial or complete closure of the sagittal and masto-occipital at an early age (ibid.).

They adopted Broca's arrangement of complication of sutures, degrees of closure and subdivision of particular sutures, except for the adoption of Frederic's inversion of Broca's categorization of the amount of suture union (i.e. 0 = no union and 4 = complete closure; 1 to 3 refer to the amount of union - one quarter... three quarters). They did not differentiate between union which had progressed halfway along a suture and closure which involved a total of half the length of a suture, but is exhibited in separate, discrete areas (Todd and Lyon 1924:336).

The following information was recorded, as the joint observation of two individuals (Todd and Lyon 1924:331-332): sample crania number, race, sex, age, greatest length, greatest breadth, cephalic index, cranial capacity and sites of Wormian bones. The observations were only accurate for the external and internal surface of the crania, with no accurate information regarding suture conditions within the skull wall (ibid.). The closure for each suture was then averaged and plotted. Todd and Lyon (1924:333) state that in spite of individual differences, there was a definite trend in the progress of suture closure in relation to age.

Todd and Lyon (1924:333) then repeated the above procedure with the male Negro and female crania (of both 'racial stocks'). This led to the elimination of 'abnormal' progress in each of the series, giving a basis for comparison of closure progress in each sex and stock with those of the male Whites, which were thereafter used as a standard (ibid.).

They observed the following traits (Todd and Lyon 1924:333): 1) there was a clear orderly age sequence in the process of suture closure; 2) sex, racial stock, cephalic index and cranial capacity have very little effect on this closure sequence; and 3) the timing of the sequence was more obvious endocranially than ectocranially (ibid.).

In attempting to graph their results, Todd and Lyon (1924:334-335) decided not to arbitrarily subdivide age into units of one year. Instead, reasoning that each year of life includes, at the maximum, 18 months and successive 'years' overlap; the states of union for all individuals during three successive years of life was summed up, and the average taken in order to calculate a mean value for the state of union characteristic of the second of the three years. This 'three year averaged' age would become the focus of later criticism, since it apparently provided absolute ages at which a specific sutural phase would be exhibited. Their error was not including this averaged age in their tabulated results alongside the 'arbitrary' age ranges. For example, Todd and Lyon (1924:361) state that for white males, endocranial vault suture closure commences in the following order sagittal (22-23 years), coronal (24 years) and lambdoid (26 years), while

closure is completed at 35, 41 and 47 years, respectively. Based upon these results, Todd and Lyon (1924:362) proposed that the rate of cranial suture closure was linked to the final stages of skeletal growth.

In order to test their findings, Todd and Lyon (1924:379) examined 30 randomly selected crania of known age. While, on average, their method provided close approximations of age at death, with a standard deviation of 6 years, it varied across individual crania (ibid.). Although, in comparison with later, revised methods of cranial suture estimation, Todd and Lyon did manage to produce estimated age ranges within 20 years of the actual age at death. However, Todd and Lyon (1924:380) stated - our results are of distinct value however, when taken in conjunction with indications given by other parts of the skeleton.

In 1925, Todd and Lyon published three follow papers to the above study (Parts II-IV).

Part II (Todd and Lyon 1925a) was an examination of ectocranial suture closure in adult males of white stock, since they acknowledged that in some instances, researchers would not be able to observe endocranial sutures. The sample consisted of the 267 crania employed in the first study, however, new samples were added for comparison as they became available during the course of these three studies (Todd and Lyon 1925a: 24). This investigation concluded that (Todd and Lyon 1925a:36): 1) in general, there is no tendency on the part of sutures to begin to close earlier endocranially, rather than ectocranially; 2) the only exceptions to this finding were the pattern exhibited by the inferior masto-occipital, the spheno-frontal and the coronal; 3) ectocranial closure was slower and more variable, with no evidence of periodic activity; 4) ectocranial suture union was never as complete as endocranial closure; and 5) ectocranially, lapsed union is evident in all sutures.

In Part III (Todd and Lyon 1925b) of their research, Todd and Lyon focused upon endocranial suture closure in the 'American negro'. They believed that this was an important area of study since they were attempting to ascertain whether or not their first study, of white males, could be employed as a standard for identifying age at death for different 'racial stocks' (Todd and Lyon 1925b:48). The initial sample consisted of 120 crania of known age from the Hamann collection. However, 41 crania were discarded for exhibiting abnormal traits, just as had been done in the two previous studies (Todd and Lyon 1925b:48). Todd and Lyon concluded that, allowing for individual variation amongst the Negro crania, the endocranial closure pattern was generally the same as for the white sample (ibid.). However, they also conclude that many Negro skulls have been rejected as abnormal because of delay in closure of the lambdoid suture. It appears that some change is even now taking place in this region of the negro cranium which would indicate that they believe there is something different occurring within the 'negro stock', or, in more current terminology, there seems to be a population specific genetic variation in the endocranial closure of the lambdoid suture (Todd and Lyon 1925b:48).

In Part IV, Todd and Lyon (1925c) examined the occurrence of ectocranial suture closure in the male Negro cranium. The sample consisted of the 79 crania selected for Part III of their study (Todd and Lyon 1925c:150). Their findings are as follows (Todd and Lyon 1925c:167-168): 1) endo and ectocranial suture closure patterns are essentially the

same for white and negro males; 2) ectocranial closure is more erratic, slower and less complete than endocranial closure; and 3) lapsed union is characteristic of all ectocranial sutures, although it does not appear in all individuals.

In summary, Todd and Lyon (1924, 1925a, 1925b, 1925c) found the following age sequence for cranial suture morphology:

Suture	Endocranial			Ectocranial		
	Open	Partial	Closed	Open	Partial	Closed
Sagittal	<23	20-37	>34	<24	23-30	>29
Coronal	<25	23-38	>36	<26	23-84	>26
Lambdoidal	<26	24-43	>41	<26	25-84	>30

These age ranges were applicable for both white and Negro males (no racial differences in suture closure), and were a few years younger for females of both racial groups. When this methodology was tested on a random sample of 30 crania of known age, the standard deviation from the 'real' age at death was +/- 6 years.

	Open	**Partial**	**Closed**	**Open**	**Partial**	**Closed**
Suture	**Endocranial**			**Ectocranial**		
Sagittal	<23	20-37	>34	<24	23-30	>29
Coronal	<25	23-38	>36	<26	23-84	>26
Lambdoidal	<26	24-43	>41	<26	25-84	>30

Cattaneo, Cobb and Singer

In 1937, Cattaneo studied 100 'miscellaneous' Argentinean skulls, and stated that suture closure could only provide a suggestive age indicator (Krogman 1962:86). Hrdlicka (1939 cited in Krogman 1962:86) stated that endocranial suture closure was only reliable within ten years on either side of the predicted age. Cobb (1952:840 cited in Krogman 1962:86), using the Todd and Lyon methodology, stated suture closure was only reliable within nine years on either side of the predicted age. In 1953, R. Singer concluded that using cranial sutures as an estimation of age at death was an unreliable assessment methodology (Krogman 1962:86). He found that there is a tendency for the cranial sutures, of both females and males, to either remain open throughout life or to close much earlier than predicted by Todd's method (Singer 1953:56).

Brooks

In 1948, S. Brooks, at the suggestion of Dr. McCown of the University of California, had begun an inquiry into why samples of aboriginal California Indians showed a mean age at death consistently less than 30 years (Brooks 1955:568). The method employed attempted to employ Todd's methods of age determination, using both cranial suture closure and changes to the pubic symphysis, to see if they were applicable to races other than white and negro, and to determine the correlation of these two methods when applied to one individual (Brooks 1955:568). However, Brooks (1955:571) attempted to examine the cranial sutures and pubic symphysis in isolation from the rest of the skeleton, as single variables, which, according to Todd and Lyon (1924) is neither a reliable nor valid methodology.

In 1948, just fewer than 400 individual skeletons from the University of California collection were selected for testing (Brooks 1955:569). In 1950, the some of the skeletons employed by Todd from the Hamann Museum collection were used for review (ibid.). Later, in 1953, a second series of 70 skeletons were analyzed to verify the methodology (ibid.). The sample was chosen based on the following criteria: 1) the individual be over 18 years of age, as judged by long bone epiphysis-diaphysis union and fusion of the three elements of the acetabulum; 2) the crania vault must contain at least the area of the coronal, sagittal and lambdoid sutures; and 3) the symphyseal surface of at least one pubic bone must be preserved (Brooks 1955:569). It should be noted that all of the skeletons were from California, but no consideration was made of area or archaeological horizon (ibid.).

Sex determination was based upon: 1) the ischio-pubic index, wherever possible; 2) breadth of the sciatic notch; 3) subpubic angle; and 4) the general morphology of the skull and mandible (Brooks 1955:570). Following the criteria of expected suture closure set out by Todd (1924; 1925a, 1925b, 1925c), Brooks employed a 5 point scale (0 - open to 4 - complete closure) (Brooks 1955:570). She (Brooks 1955:571) stated that there was "no way of checking the accuracy of either cranial or pubic ages, should they be divergent in one individual, except by indirect approach."

Brooks (1955:573) found that, for females, there was a "sharp deviation" for the predicted age at death between cranial suture and pubic symphysis methods, of at least 10 years. She states that cranial suture closure tends to lag anywhere from 5 to 25, with a mean of +/- 9 years, behind that of the pubic symphysis (Brooks 1955:573). The male sample showed a deviation from 5 to 8 years, with a mean of +/- 2 years, between cranial suture and pubic symphysis methods (Brooks 1955:574). Brooks found that in cases where all of the sutures were open (predicted age <25), comparison with dental wear patterns, epiphyseal closure and pubic symphysis surface, all indicated that the specimen was over 35 years old (Brooks 1955:582). Despite obtaining linear correlations as high as 0.74, these results led her to concur with Singer (1953), that cranial suture closure was an unreliable method of age determination, especially for female skeletons (Brooks 1955:588; Meindl and Lovejoy 1985:57).

McKern and Stewart

In 1957, McKern and Stewart revised the cranial suture closure methodology (Krogman 1962:82). Following the work of Singer (1953), they assigned four parts to the coronal and sagittal sutures and three to the lambdoidal sutures, but followed Todd and Lyon in the five scale rating system (0-4, but 2-3 are combined) (Krogman 1962:82). However, their observations were based solely upon ectocranial suture closure (Krogman 1962:83). McKern and Stewart (1957) noted that closure tends to begin the the 1st and 4th parts of the coronal, 1st part of lambdoid, and 1st and 4th parts of the coronal (ibid.). The final stage of closure tends to be in the 1st and 2nd parts of the sagittal, 1st or 2nd part of lambdoid, and the 1st part of the coronal (ibid.). Although they found that there was an age progression in the uniformity of suture closure, they believed that it was too erratic to be of use in determination of age at death (McKern and Stewart 1957:37). McKern and Stewart (1957:37) concluded that:

So erratic is the onset and progress that an adequate series will provide just about any pattern at any age level. Thus, as a guide for age determination, such a trend is of little use.

Genovese and Messmacher

In 1959, Genovese and Messmacher studied 101 Mexican male skulls of all ages and known identity: 47 ‘indigenas’ and 54 ‘mestizos’ (Krogman 1962:87). They found that the age difference between suture estimation and actual age was 12 years, 11 months (indigenas) and 9 years, 5 months (mesitzos) (ibid.).

Meindl and Lovejoy

In 1985, Meindl and Lovejoy re-examined the Hamann-Todd Collection. They chose 10 ectocranial landmarks, although it is unclear whether they scored for bilateral expression (Meindl and Lovejoy 1985:60). They employed the following scoring methodology: 0 - no observable closure; 1 - 1 to 50% closure; 2 - 51 - 99% closures; 3 - 100% closure. Small (1 cm) lengths of a suture or specific sites were selected for inspection, for which only the judgment of one observer was required (Meindl and Lovejoy 1985:58). Since they proposed that in the case of forensic anthropology, the regularity of closure during the early adult years was not critical, only ectocranial sutures were studied (ibid.). Meindl and Lovejoy (1985:58) thus chose 17 ectocranial points for 236 crania from the Hamann-Todd collection, based upon the reliability of stated age at death.

During the initial analysis, they found that some of these landmark sites were of limited value for consistent age determination (Meindl and Lovejoy 1985:58). These sites were as follows (Meindl and Lovejoy 1985:58-60): (closure of) 1) parieto-mastoid; 2) squamosal point; 3) occipito-mastoid; 4) zygomatic and malar; 5) frontolacrimal; and 6) frontoethmoid. The sites which were retained (Meindl and Lovejoy 1985:60) were the vault system (midlambdoid, lambda, obelion, anterior sagittal, bregma, midcoronoal and pterion) and lateral anterior system (midcoronoal, pterion, spheno-frontal, inferior sphenotemporal and superior sphenotemporal). Meindl and Lovejoy (1985:60) found a chronological age ranking at the pterion, sphenofrontal, midlambdoid and lambdoid, respectively. These were based upon the assumption of underlying continuity of ordinal closure scales (the Kendall coefficient) (ibid.).

The next phase of analysis, to determine combination of sites which could be employed in age estimation, was based upon the following assumptions (Meindl and Lovejoy 1985:61): 1) sutures should demonstrate a protracted sequence of closure; 2) sutures should correlate with age during the primary period of its closure activity; and 3) the information provided by each suture should be specific to that particular suture. From these criteria, and since the calotte is usually the most durable in archaeological populations, they determined that the 5 lateral anterior sites were the best overall predictor of age (Meindl and Lovejoy 1985:61). It was assumed that the sample crania would exhibit a commencement and termination sequence which correlated with long bone epiphyseal fusion sequence (Meindl and Lovejoy 1985:62).

Using composite scores for each sample specimen, they found that the lateral anterior sites closed in the following sequence: Commencement - pterion, midcoronal, sphenofrontal, inferior sphenotemporal, superior sphenotemporal; Termination - pterion, sphenofrontal, midcoronal, inferior sphenotemporal, superior sphenotemporal (Meindl and Lovejoy 1985:63). The vault sutures closed in the following sequence:

Commencement - obelion, pterion, anterior sagittal, lambda, midlambdoid, midcoronal, bregma; Termination - obelion, pterion, anterior sagittal, lambda, bregma, midlambdoid, midcoronal (ibid.). The overall (linear) correlation with known age was 0.57 for lateral anterior sites and 0.50 for vault sutures (ibid.).

It was found that the average mean deviation, for lateral anterior scoring, was 7.5 years, and 14.2 years for vault sutures (Meindl and Lovejoy 1985:64). Meindl and Lovejoy (1985:64-65) also examined whether or not race or sex had any effect on suture closure, thus affecting the accuracy of age prediction. Using analysis of covariance (ANCOVA) on the residuals, they found no measurable influence of either race or sex (ibid.). However, Meindl and Lovejoy (1985:62) state that any age estimation should take into account postcranial indicators as a control for suture cranial variations.

Buikstra and Ubelaker

In Standards for Data Collection from Human Skeletal Remains, Buikstra and Ubelaker (1994) proposed combining several aging methods, based on different cranial sutures (Baker 1984; Mann et. al. 1987; Meindl and Lovejoy 1985; Todd and Lyon 1924, 1925a, 1925b, 1925c) to predict age. According to Hershkovitz et. al. (1997:394), this ‘refined’ method ignored the fact that correlation between the recommended areas for inspection, along the cranial sutures, and age are very low. They (Hershkovitz et. al.

1997:394) proposed that these new standards still turn out old results, which seems to be apparent in their own research of cranial suture closure.

Nawrocki

In 1995, Nawrocki examined all three categories of sutures (ectocranial, endocranial and palatine) using regression and analysis of variance techniques (Nawrocki 1998:276). He studied 100 individuals of known sex, age and race (black/white) from the Terry Collection. Two individuals were chosen from each race/sex category in every half decade, ranging in age from 21-85 years (Nawrocki 1998:277). Although for whites, the lowest age was 27. No specimens were excluded for any reason; barring damage therefore there was

no control when examining 'abnormal' skulls (ibid.). Following Meindl and Lovejoy (1985:60), 27 landmarks were scored on each skull: ectocranial (16), endocranial (7), and palate (4) (Nawrocki 1998:278). Both the left and right side of the skull were scored when bilaterally expressed (ibid.).

A second sample was obtained in order to test the results from the Terry sample. This consisted of the crania of 61 white individuals (27 males; 34 females), aged 58-102 years, obtained from medical dissection rooms in Syracuse and Indianapolis (Nawrocki 1998:279). However, while Nawrocki (1998:279) notes that the presence of soft tissues and saw cuts on the cranial vault, limited suture observations of the endo and ectocranial surfaces, he does not indicate how the age at death of the sample crania was verified.

In order to produce a score, all 27 landmarks were added together, resulting in a range of 0-81 (Nawrocki 1998:279). It was found that there was a moderately strong correlation between the predicted age and the age of the Terry samples (Nawrocki 1998:279). However, Nawrocki (1998:281) does note that summing or averaging the data will result in a loss of information. One area of possible concern, regarding this reliance upon linear regression models, is that it allows for a predicted range from 25.3-82.8 years, even though the sample crania were 58-102 years old (Nawrocki 1998:279).

Additionally, when tested against the Terry samples, the predicted ages deviated, on average, between 9 to 21 years (Nawrocki 1998:286). It should be noted that Todd's average age deviation was 6 years, which he deemed to be unacceptable.

Creating an equation to test Meindl and Lovejoy's proposal that race or sex may affect suture closure rates, Nawrocki found that there was a correlation between suture closure and sex, but not race, although there was an interaction between race and sex (Nawrocki 1998:282). He suggests that this finding, which is contrary to that of Meindl and Lovejoy, is due to the use of more cranial landmarks (ibid.). Nawrocki (1998:282) created 8 different equations to test each case sample, although this required dropping the number of landmarks from 27 to 15.

In his conclusion, Nawrocki (1998:288) proposes two possible sources of error: sampling (random) and secular trends (non-random). Sampling error is said to occur when the two parent populations are similar overall, yet the test sample is drawn unevenly (ibid.).

However, this seems to be a rather weak argument, considering the emphasis placed on obtaining 'random' samples for statistical analysis. Secular trends systematically change the nature of the second population, or portions of it, so that the regression derived on the first are no longer as accurate (Nawrocki 1998:288). In this instance, one is concerned that the sample is too randomly varied. In other words, researchers seem to prefer finding fault with the 'sample' rather than with their chosen methodology

Hershkovitz et. al

In 1997, Hershkovitz et. al. examined the extent of the sagittal suture closure in 3,636 skulls from the Hamann-Todd and Terry collections (Hershkovitz et. al. 1997:393). The sagittal suture was chosen (Hershkovitz et. al. 1997:395)

As it is the only ‘end-to-end’ type suture in the calvaria (avoiding ‘‘pseudoclosure’’ due to overlapping of bone, as in frontal over parietal bone), and because its location at the midline neutralizes it from biomechanical influences.

Hershkovitz et. al. (1997:395) identified five sutural conditions, defined as: 1) totally closed (TC): no signs of the sagittal suture were observed on the ectocranial surface, from bregma to lambda; 2) partially closed (PC): less than 10% of the suture length was open; 3) totally open (TO): the suture line was clearly visible with almost no interruptions along its entire length, from bregma to lambda. Minor closure at the area of the parietal foraminae was ignored; 4) partially open (PO): between 10% and 90% of the suture length was open; and 5) premature suture closure (PMSC). PMSC was distinguished from pathological closure, which occurs very early in life (5 years or earlier), and which is characterized by sutural ridging (i.e., scaphocephally) (Hershkovitz et. al. 1997:395). In the PMSC category all skulls in which the sagittal suture was closed after the age of 5 years but before 18 years, were included (ibid.).

Hershkovitz et. al. (1997:398) provide the following conclusions: 1) the sagittal suture cannot be used for aging the skeleton; 2) although cross-sectional in nature, suture obliteration patterns are not temporary progressive stages on an age scale, but rather independent permanent phenomena; 3) some suture closure patterns are genetically inherited; 4) females and males manifest different suture closure patterns; 5) in all ages, the relative frequency of the ‘‘totally open’’ category is higher in females than in males; 6) the medical conditions (HFI, TB) examined in the present study are not associated with a suture closure condition; and 7) suture closure is neither a pathological phenomenon nor the result of normal aging process. Taken as a whole, the authors state that reliance upon cranial suture closure for age estimation is of no value for either forensic application or paleodemography studies (Hershkovitz et. al. 1997:397).

Cattaneo .L (1937) reported on 100 skulls and commented that suture closure is only a suggestive indicator of age .Mckern and Stewart (1957) concluded that progress of suture closure has only a very general relationship with age. Estimation of age of skull from suture closure is not reliable Reddy K S N ,because it can be given only in a range of decades .The study by Vyas P.C showed that closure of sutures although not an appropriate indictor of age yet ,accuracy in age estimation in elderly persons can reasonably achieved if other indicators of ageing process are taken into consideration .e.g.-graying of hair ,wrinkles ,arcus senalis ,menopause and teeth.

Gustafsons, G. (1950) also stressed on condition of teeth in age estimation among the elderly persons along with ossification of bones. Sequential closure of various skull sutures imparts valuable information regarding the age of the person. Over the age of 25 and especially nin 25-40, the estimation of age becomes more difficult. For many years the closure of skull sutures was considered most accurate method (Keith Mant A, 1994). It is common knowledge that most adult have at least part of their sutures closed and this tends to become more wide spread as the age increases. There are many exceptions and as the rate of closure is not linear with time. This generally can be useful when skull came from a mature individual, as it is unlikely below the age of 20 Broth well Bernard Knight ,(1996).according to Rantoul,E.and Smith ,H(1973) the absence of

any sign of closure of any of the skull points to strong probability that the age does not exceed 30 years.

Three age estimation techniques using ectocranial and/or endocranial suture closure are tested on a sample of known age from Spitalfields, London in order to determine the value of cranial suture closure as an indicator of age at death. The three techniques are those proposed by Acsádi and Nemeskéri, Meindl and Lovejoy and Perizonius. Results indicate that the Acsádi and Nemeskéri technique, which is based on endocranial sutures, can be used to distinguish young and middle-aged individuals in the Spitalfields sample but gives no information for crania over the age of 50 years. Age estimation using the Meindl and Lovejoy and Perizonius (Old system) techniques, which use ectocranial sutures, was found to be subject to a number of complicating factors, of which sexual dimorphism in the rate and pattern of closure is the most significant. A method of estimating age at death based on both endocranial and ectocranial suture closure is developed on the basis of the Spitalfields sample. The technique attempts to overcome some of the problems associated with both intra- and interpopulation variation in cranial suture closure. For a truly accurate age-estimation technique based on cranial suture closure we would need to know more about the causes and functions of suture closure in human populations.

According to Brash(1937), growth changes in the skeleton, although providing a very reliable basis for estimation of age, do not permit of an exact determination , but only within a range ,since there is variation in relation to growth and age.

Franchini (1938) after examination of 629 skulls (369 male and 260 females) observed that the obliteration of sutures may be of subsidiary help in association with other appearances but the variations are such that it is impossible to rely it alone for determining the age of subject.

According to Krogman, suture closure begins endocranially and proceeds ectocranially; i.e. it begins inside the skull and progress to the outside.

In 1890, Dwight found that suture closure begins endocranially and it spread outwardly to ectocranium. He concluded that, the time of closure of any particular part of the suture and the order in which the process advances are very uncertain. But according to him endocranial closure is more reliable than ectocranial fusion.

In 1981, Patil T.L. et al studied closure of cranial suture of vault of skull in 150 skulls for macroscopic suture closure and observed that sequence of closure is not constant; it proceeds more quickly in endocranial sutures and reaches to higher degree.

According to Robert Shapiro and Janzen, A.H. (1960) the sutures begin to close on both the outer and inner aspects of the calvarium at about same time. However, ectocranial suture proceeds more slowly, so more individual variation and is generally not complete as endocranial union. Furthermore, the sutures along the outer table are more or less serrated while those on the inner table are comparatively straight. When the suture line is produced on the skiagram that may simulate fissure fracture. A good rule of thumb is to refrain from making the diagnosis of a fissure fracture in a suture unless there is a sufficient suture diastesis.

According to Nandy,A.(1995) skull sutures start their fusion activity by 24-25 years of age ,which usually starts at the ectocranial surface but, though they start in the endocranial surface occurs late the progress at this level is speedy, more uniform and more complete then at the ectocranial level. Hence the endocranial fusion is more reliable than ectocranium. They ossify and are completely obliterated in the advanced age, although the parietal suture may remain separate throughout life.

Lapsed union as the term implies, it is incomplete union in the sense that a process once begun has not gone on to completion.

Todd and Lyon (1924) found no onset timing difference between endocranial and ectocranial closure, but found the former more reliable age indicator since the later so frequently showed lapsed union. Lapsed union occurs more often in sagittal suture (Reddy K.S.N).

McKern and Steward (1957) studied the observation on ectocranial suture closure only, says, lapsed union is characteristic of all ectocranial sutures. In 1910 Jones observed that the external closure of the sutures may, however, be but very little evident when within the skull the obliteration of sutures is complete. Ectocranial sutures tend to remain in a state of incomplete union, some in very high degree.

The metopic suture which is placed between the two frontal bones and closes between 2-7 years Nandy,A.(1995), but some time metopic suture may remain persisting Montague and Tongerson,(1951). Such metopism has been assessed at 0-7.4% individuals in various ethnic groups Berry, A.C (1975), 3.4% in Nigerian skull (Ajmani et al, 1983) and 10% in Mongoloids Woo, (1949). According to Tongerson, the tendency towards persistent metopism is inherited as a Mendelian dominant trait.

Determination of age goes on becoming difficult as the age advances particularly after the age of 40 years with conventional methods. To overcome this problem a study has been conducted where 100 cases with age range of 40-70 years were taken. The study different levels of suturesnof skull on CT scan. The closures of lambdoid, parieto-mastoid, coronal and squamous sutures were studied and grading and grading was done depending upon closure of sutures. Each suture was found to close at particular age group. Each individual was exposed to CT scan and 3 axial sections were taken for each individual. Earliest union was found to be 40-45 years. Age of fusion was found to be Lambdoid (45-50),Parieto-mastoid(55-60),Squamous (60-65),Coronal(45-50).

A study was conducted in 1998 in which a total of 963 skeletons were studied to examine macroscopic cranial methods of age estimation. The methods of Ascadi-Nemeskeri, Masset, Baker and Meindl-Lovejoy were applied to every skull. The results indicated that most accurate technique in this application were those that consider endocranial suture closure. The methods of Ascadi-Nemeskeri and Masset were the most accurate in all sub-samples by population, sex, within population and in total.

Although the relative accuracy could vary in application to the other populations.[5] Time of closure of sagittal,coronal, and lambdoid sutures were studied at autopsy on 538 male and 127 female adults of known ages belonging to north-west India . Whether a segment was open or closed on either surface was recorded. On analyzing the records authors came to conclusions that obliteration of sutures commences earlier on endocranial surface than on ectocranial. Complete obliteration of a segment or the

entire suture is so erratic that it is not useful for estimating the age of skull.[6] The age of 20 males and 20 females was evaluated based on vault sutures. The results were compared with the actual chronological age of the deceased calculated on the basis of their date of birth and demise. In many cases a slight overestimation occurred in evaluating the age by analyzing the sutures. Thus the results show that a precise and thorough evaluation of the deceased's age is not possible on the basis of cranial suture closure without maceration of the skull.[7]

A study was conducted which used age estimation on the base of single rooted tooth and cranial suture obliteration on unknown persons. A comparison of the estimated age and chronological age derived after identification showed high usefulness of the mentioned methods.[8]

Meindl-Lovejoy method was applied to 3663 skulls from Hamman-Todd and Terry collection. It was found that sagittal suture closure was age independent and sexually biased. The wide confidence intervals appeared to preclude meaningful application of suture status for age determination. No correlation was found with tested biological stressors.[9]

A new method was applied using ectocranial suture closure of lateral anterior and vault suture on 236 samples from the Hamman-Todd collection. It was found that ectocranial method was superior to endocranial and that age estimates are independent of race and sex. Conclusion was that the suture closure can provide valuable estimates of age at death in both archeological and forensic context when used in conjunction with other skeletal age indicators. [10]

A study conducted on 256 crania of adults over 20 years of age using Acsadi-Nemeskeri method found usefulness of this method for age estimation.[11]

Another study using three age estimation techniques (Acsadi-

Nemeskeri, Meindl-Lovejoy and Perizonius method) tested on a sample of known age in order to determine the value of cranial suture for age estimation. The results indicated that Acsadi-Nemeskeri technique which is based on endocranial suture can be used to distinguish between young and middle aged individuals in the sample but gives no information for crania over the age of 50 yrs. Age estimation using the Meindl-Lovejoy and Perzonius old system techniques, which use ectocranial sutures, was found to be subject to numerous complicating factors of which sexual dimorphism in the rate and pattern of closure was most significant. A method of estimating age at death based on both endo and ectocranial suture was developed on the basis of study sample. The technique attempts to overcome some of the associated with both intra and inter-population variation in cranial suture.[12]

.

AIMS AND OBJECTIVES

1. To study the chronology and pattern of union of cranial sutures namely coronal, sagittal and lambdoid etc.

2. To detect bilateral and bisexual variations in cranial suture closure if any.

3. To specify the relationship between progression of union of cranial suture and age of the subject.

4. To formulate a practical method of estimation of age based on the status of the progression of the closure of sutures using the data collected.

MATERIALS AND METHODS

The study was conducted on cases coming for medico-legal postmortem examination to the Department of Forensic medicine, Maulana Azad Medical College, New Delhi, during a period of 2007 to march 2008.

Study design

A descriptive cross-sectional study.

Inclusion criteria

1. The cases of known age coming for medicolegal postmortem examination. Age was confirmed by documentary evidences like birth certificate, identification cards, ration card..etc.

2. Subjects of more than 20 years of age were taken.

Exclusion criteria

1. Unknown, unclaimed bodies where exact age cannot be confirmed.

2. Cases showing deformed or diseased or fractured skull, which may hamper the study of suture closure.

Methods

100 cases of age 20 and above were studied. Documentary proof of age was collected. After reflecting the scalp, coronal, sagittal, lambdoid sutures were studied applying Acsadi-Nemeskeri scale ectocranially. For endocranial same score system was applied after removing the calvaria by craniotome taking due care to include complete coronal and sagittal suture. Lambdoid suture was studied in-situ. The calvarium was cleaned of soft tissues on both sides and was dried, which made the sutures more prominent. Photographs were taken in all cases. The obliteration of the sutures was ascertained endocranially as well as ectocranially. In both cases degree of closure was scored in 16 parts of the main cranial sutures as has been done by Acsardi-Nemeskeri[13].

The coronal suture was studied in three parts on right side and left side each; sagittal suture in four parts and lambdoid sutures in three parts each on right and left side.

Ectocranially the different sections were distinguished by differences in the character of the suture. Endocranially the sutures do not show these differences in character.

Consequently the endocranial sutures were simply divided in sections of equal length.

Scale for closure: Acsadi-Nemeskeri complex method
0 = open. There is still little space left between edges of adjoining bones.

1 = incipient closure. Clearly visible as a continuous often zigzagging line.

2 = closure in process. Line thinner, less zigzags, interrupted by complete closure
3 = advanced closure. Only pits indicate where the suture is located
4 = closed. Even location cannot be recognized.

Mean ectocranial as well as endocranial closure stages were calculated for the three main sutures by adding the scored closure stages of the different sections and dividing the result by number of sections which compose the suture in question.

Endocranially closure indices were calculated in similar fashion adding the closure stages of all the sections and dividing the result by 16[11,14]A detailed pre-designed Performa was completed for every case studied.

Statistical Methods

To estimate the possible relation between suture closure and age at death, appropriate statistical tools were used (spearman rank correlation coefficients, Levene's test for equality of variances, student's t test for equality of means, SPSS software). $p < 0.05$ was considered as significant.

The study consisted of 100 cases brought to the mortuary of Maulana Azad Medical College and Lok Nayak Hospital, New Delhi during the period of January 2007 to March 2008.

AGE AND SEX DISTRIBUTION

The age of the victims varied from 20 to 90 years. Age groups were classified 10 year interval so as to compare with the previous studies.(Table 1, 2) It was observed that maximum number of cases were in 20-29 age group which also tells us regarding the age distribution of cases coming for autopsy in MAMC. There were 38 cases i.e. valid percentage is 38 and cumulative is 38. In 30-39 groups there were 25 cases, valid percentage is 25 and cumulative is 63%. In 40-49 age groups, there were 10 cases which accounts for 10% of the total cases and cumulative is 73%.11% of the cases were constituted by 50-59 age group. (Cumulative percentage is 84). There were 10 cases in 60-69 age groups. It constituted 10% of cases and cumulatively 94%. There were only 6 cases in 70 years and above which is about 6% of total and cumulative percentage is 100. The minimum age of case is 20 and maximum age is 90, mean is age is 38.36, standard deviation is 16.794 and median age is 34.50.

Table 1

Age groups	Frequency	Percent	Valid Percent	Cumulative Percent
20-29	38	38.0	38.0	38.0
30-39	25	25.0	25.0	63.0
40-49	10	10.0	10.0	73.0
50-59	11	11.0	11.0	84.0
60-69	10	10.0	10.0	94.0
>= 70	6	6.0	6.0	100.0
Total	100	100.0	100.0	

Table 2

N	Minimum	Maximum	Range	Mean	Std. Deviation	Median	Std. Error of Mean
100	20	90	70	38.36	16.794	34.50	1.679

SEX DISTRIBUTION

Males constituted a majority and comprised 72% (72 cases) compared to females who were only 28 %. (28 cases). (Table 3, 4, 5 and graph 1, 2 , 3)Male to female ratio is roughly about 4:1.

Within the age groups –in 20-29 age group 10 females(35.7%),8 in 30-39 age group(28.6%), 2 cases in 40-49 age group(7.1%), 3 subjects in 50-59 age group(10.7%), 3 subjects in 60-69 faction(10.7%)and 2 in set of 70 and above(7.1%). In males 28 subjects were in 20-29 age group (38.9%), 23.6%in 30-39 age group (17 cases), 11.1% i.e. 8 cases in 40-49 and 50-59 respectively.

In 60-69 group there were 7 cases (9.7%) and 4 cases in 70 and above age group (5.6%).

Table 3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	FEMALE	28	28.0	28.0	28.0
	MALE	72	72.0	72.0	100.0
	Total	100	100.0	100.0	

Table 4

		AGE GROUP						Total
		20-29	30-39	40-49	50-59	60-69	>= 70	20-29
FEMALE	Count	10	8	2	3	3	2	28
	% within	35.7%	28.6%	7.1%	10.7%	10.7%	7.1%	100.0%
				SEX				
MALE	Count	28	17	8	8	7	4	72
	% within	38.9%	23.6%	11.1%	11.1%	9.7%	5.6%	100.0%
				SEX				
Total	Count	38	25	10	11	10	6	100
	% within	38.0%	25.0%	10.0%	11.0%	10.0%	6.0%	100.0%
				SEX				

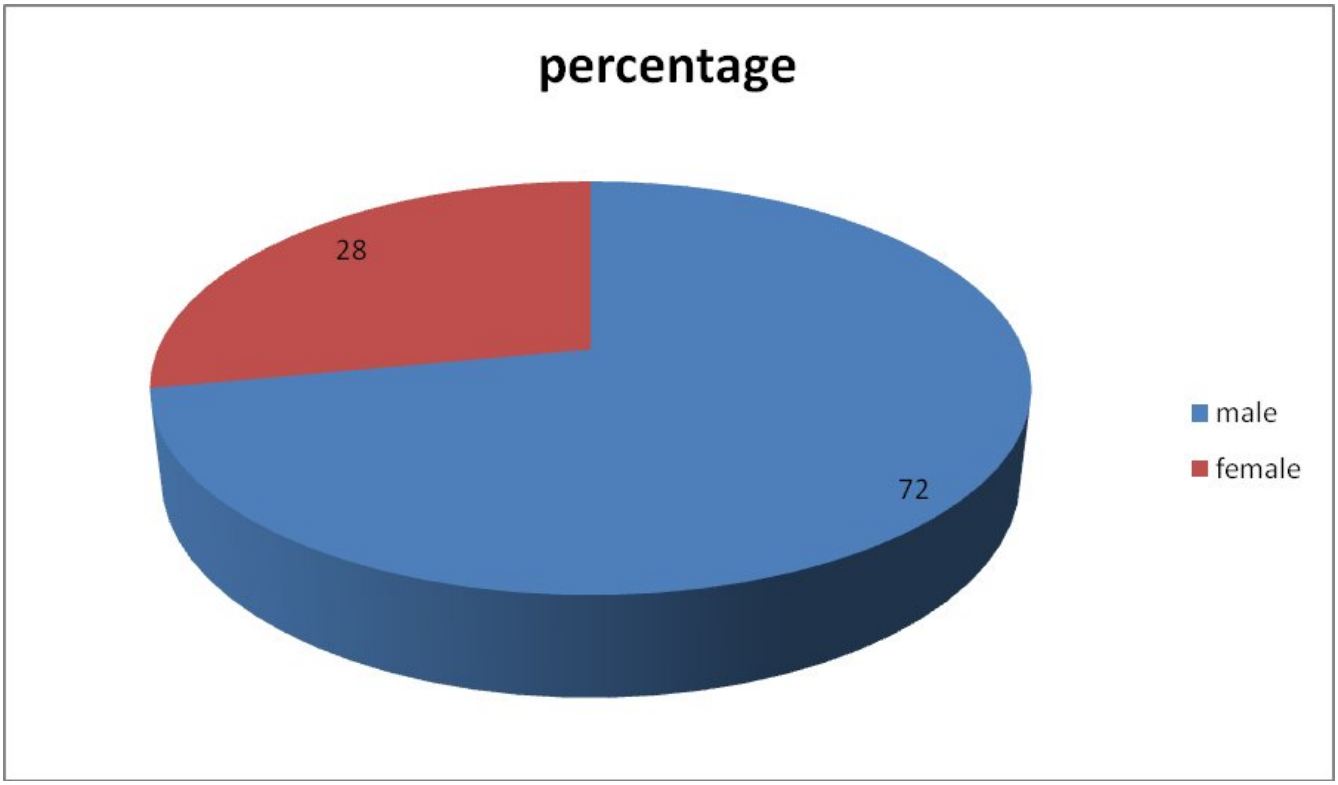
Table 5

		AGE GROUP					Total	
		20-29	30-39	40-49	50-59	60-69	≥ 70	Total
	Count	10	8	2	3	3	2	28
FEMALE	% within SEX	35.7%	28.6%	7.1%	10.7%	10.7%	7.1%	100.0%
	Count	28	17	8	8	7	4	72

MALE	% within SEX	38.9%	23.6%	11.1%	11.1%	9.7%	5.6%	100.0%
	Count	38	25	10	11	10	6	100
Total	% within SEX	38.0%	25.0%	10.0%	11.0%	10.0%	6.0%	100.0%

SEX DISTRIBUTION-

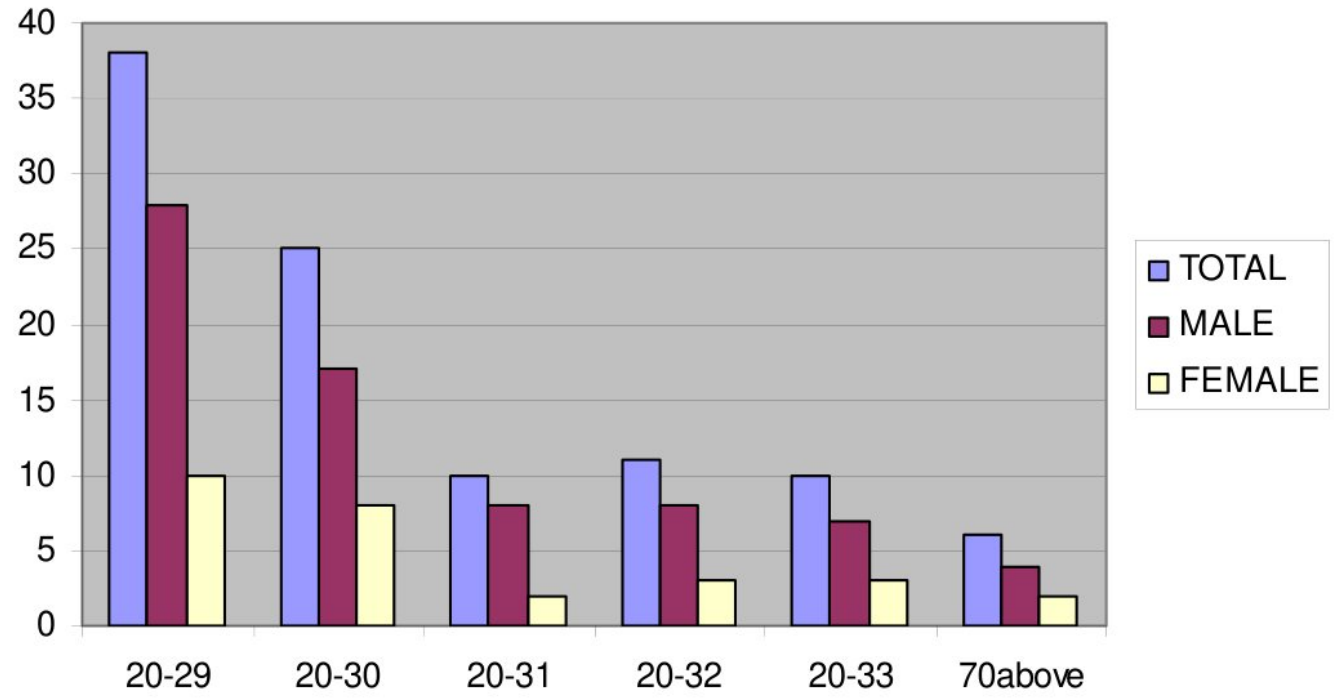
In our study there were 28 females and 72 males out of 100 cases which also represented cases coming to mortuary of our department.



Graph 1

SEX DISTRIBUTION

Male dominance was observed in all age groups.



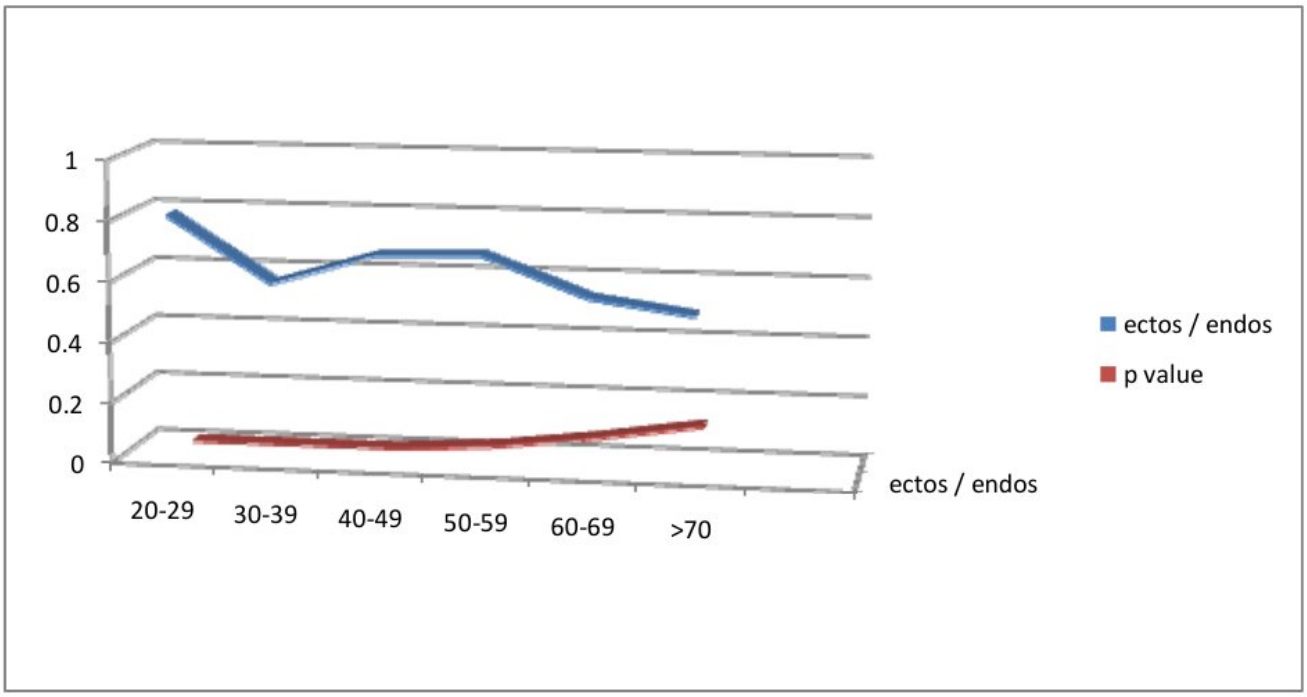
Graph 2

DISTRIBUTION OF CASES –ACCORDING TO AGE GROUP

Maximum numbers of case were seen in 20-29 age groups, least in above 70 years age group.

Graph 3 **case distribution** 6% 10% 11% 10% 25% 20-29 38% 20-30 20-31 20-32 20-33 70above

CORRELATION OF ECTO AND ENDOCRANIAL SAGITTAL SUTURE



Graph 4

Table 6

	NO.OF SUBJECTS	ECTOS/ ENDOS	ECTOCR/ ENDOCR	ECTOCL/ ENDOCL	ECTOLR/ ENDOLR	ECTOLL/ ENDOLL
TOTAL	100	.814** .000	.789** .000	.783** .000	.810** .000	.837** .000
20-29		38 .597** .623** .694** .747** .808** .000 .000 .000 .000 .000				
30-39	25	.699** .000	.737** .000	.742** .000	.520** .008	.667** .000
40-49		10 .707* .415 .010 .236 .236 .022 .233 .979 .511 .511				
50-59	11	.578 .063	.806** .003	.458 .156	.457 .157	.457 .157
60-69		10 .531 .532 .473 XXX XXX .114 .113 .168				
>_70	06	XXX	XXX	XXX	XXX	XXX

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed)

Ectocranial sutures were compared with endocranial sutures through sagittal, right and left coronal and lambdoid . (Table 6 and graph 4)To estimate the possible relation between suture closure and age at death Spearman rank correlation coefficients (2 tailed) were calculated.

Because of the considerably skewed age distribution of the sample, Pearson correlation coefficients are less appropriate. Significant correlation was found in earlier age group till 40

years of age. There after significant correlation was found sagittal suture in 40-49 cohorts (at 0.05 levels) and coronal suture in 50-59 age groups (0.01 levels).

Table 7

AGE GROUPES	NO.OF SUBJECTS	ECTOS/ ENDOS	ECTOCR/ ENDOCR	ECTOCL/ ENDOCL	ECTOLR/ ENDOLR	ECTOLL/ ENDOLL
20-29	10	.291 .415	.569 .086	.724* .018	.658* .039	.879** .001
30-39	08	.948** .000	.625 .097	.884** .004	.849** .008	.793* .001
40-49	02	XXX	XXX	XXX	XXX	XXX
50-59	03	.866 .333	.866 .333	-.500 .667	1.000** XXX	1.000** XXX
60-69	03	.000 1.000	.866 .333	.866 .333	XXX XXX	XXX XXX
>_70	02	XXX	XXX	XXX	XXX	XXX

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

In female subjects significant correlation was found in left coronal and lambdoid upto 40 years of age. (Table 7)In sagittal sutures 30-39 age set found to be correlated. In 50-59 age group cluster correlation was found in lambdoid suture. Since, female subjects were only two in 40-49 and 70 and above group, correlation cannot be found.

Table 8

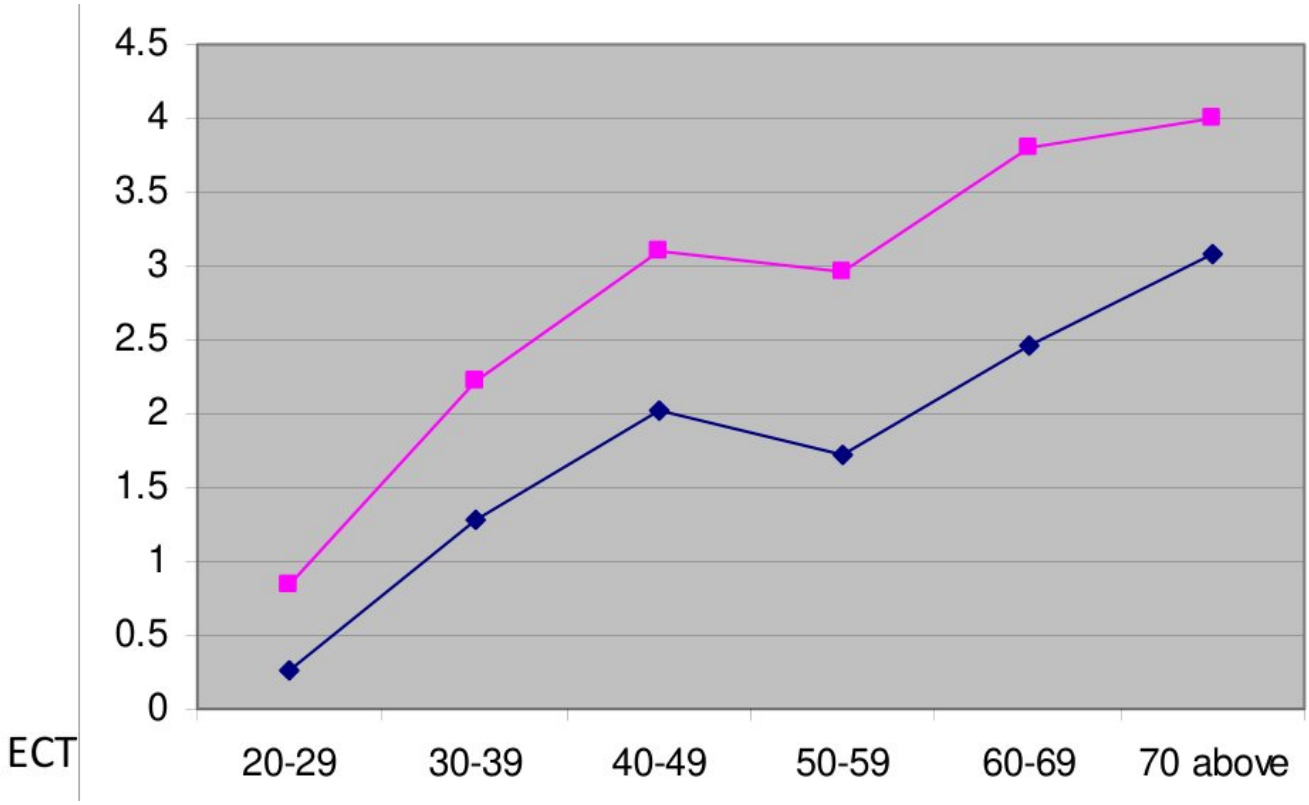
AGE GROUPES	NO.OF SUBJECTS	ECTOS/ ENDOS	ECTOCR/ ENDOCR	ECTOCL/ ENDOCL	ECTOLR/ ENDOLR	ECTOLL/ ENDOLL
20-29	28	.659** .000	.678** .000	.713** .000	.747** .000	.766** .000
30-39	17	.479 .052	.724** .001	.662** .004	.207 .424	.518* .033
40-49	08	.663 .073	.455 .258	.018 .965	.267 .528	.264 .528
50-59	08	.551 .157	.817* .013	.777* .023	.292 .482	.292 .482
60-69	07	.624 .135	XXX	XXX	XXX	XXX
>_70	04	XXX	XXX	XXX	XXX	XXX

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

In male subjects ectocranial and endocranial suture closure were found to be correlated in 20-29 age group. (Table 8) 30-39 age faction all except sagittal suture correlated.(graph 5) In 50-59 age group coronal sutures were found to be interrelated (at 0.05 levels). No correlation seen in above 60 years. Sagittal suture closure was found to be age related i.e. as the age increases suture closes except in 50-59 years. (Table 9)

ECTOCRANIAL AND ENDOCRANIAL CLOSURE OF SAGITTAL SUTURE



Graph 5

ECTO

ENDO

Table 9

AGE GROUP		N(m/f)*		Mean(m/f)		Std. Deviation(m/f)	
20-29	20-29	28	10	.93	1.70	2.124	1.636
	30-39	17	8	6.47	2.75	4.719	3.536
	40-49	8	2	8.50	6.00	5.318	2.828
	50-59	8	3	7.25	6.00	4.652	6.000
	60-69	7	3	11.86	8.33	1.864	7.506
	>= 70	4	2	13.25	11.50	3.594	.707
	Total	72	28	5.53	4.18	5.449	4.546

*m=males, f=females

When comparison between males and female subjects were made, closure was earlier in males.(mean 5.53 vs. 4.18). In 20-29 ages faction closure was seen earlier in females in ectocranial sagittal suture.

In coronal suture right and left side were compared and no significant or very minimal difference was found. When males and females were considered separately there were no significant difference between right and left side of coronal suture.

When comparison between males and female subjects were made, closure was earlier in males.

(Mean 3.38 vs 2.89 and 2.93).

In lambdoid suture right and left side were compared and no significant or very minimal difference was found. When males and females were considered separately there were no significant difference between right and left side of lambdoid suture.

When comparison between males and female subjects were made, closure was earlier in males.

(Mean 3.46 vs 3.07 and 3.38 vs 3.14).

Endocranial sutures also females have late closure, mean for total cases 8.99 vs 7.32 (except in 20-29 age groups).(table 10)

ENDOS

Table 10

AGE GROUP		N(m/f)		Mean(m/f)		Std. Deviation(m/f)	
20-29	20-29	28	10	2.93	4.50	3.516	3.979
	30-39	17	8	11.06	5.00	4.337	5.014
	40-49	8	2	12.50	12.00	3.381	.000
	50-59	8	3	13.38	8.00	3.249	6.928
	60-69	7	3	15.14	13.33	2.268	4.619
	>= 70	4	2	16.00	16.00	.000	.000
	Total	72	28	8.99	7.32	6.092	5.722

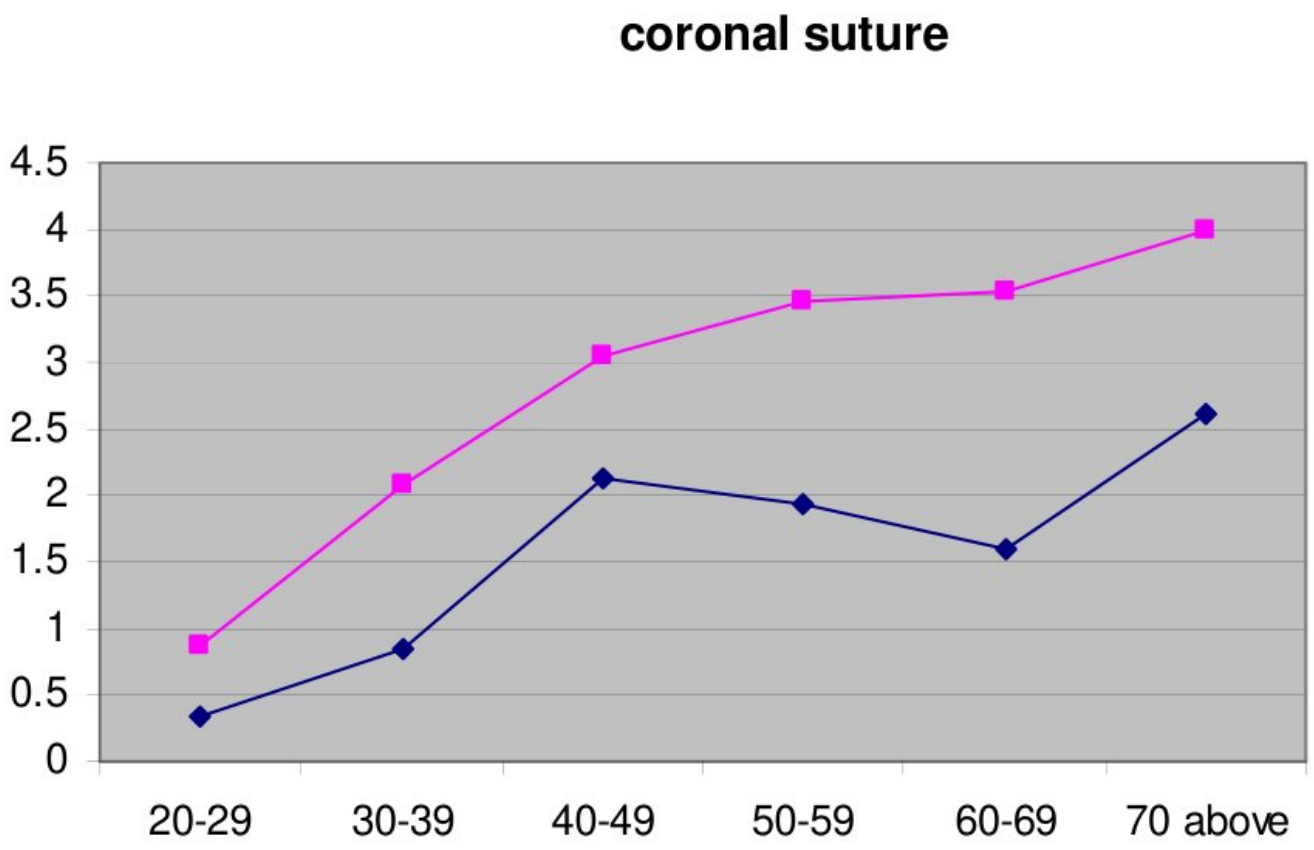
In coronal sutures also there was minor difference in closure among right and left side endocranially, which cans be safely ignored. When sexes were taken separately also there were minimal difference bilaterally.

In lambdoid suture also there were no difference in closure between right and left side. Closure occurred earlier in males in all ages except 20-29 groups.

Table 11

AGE		ECTO S1	ECTO- S2	ECTO -	ECTO-	ECTO	ECTO	ECTO
GROUP		ECTO S1	ECTO- S2	S3	S4	CR1	CR2	CR3
20-29	N	38	38	38	38	38	38	38
	Mean	.16	.24	.37	.32	.29	.29	.42
	Std. Deviation	.437	.542	.589	.525	.515	.515	.599
30-39	N	25	25	25	25	25	25	25
	Mean	1.04	1.20	1.52	1.36	.76	.80	.92
	Std. Deviation	1.172	1.118	1.388	1.287	.779	.764	.862
40-49	N	10	10	10	10	10	10	10
	Mean	2.00	2.00	2.00	2.10	1.80	1.70	2.90
	Std. Deviation	1.333	1.333	1.155	1.197	.632	.675	2.923
50-59	N	11	11	11	11	11	11	11
	Mean	1.55	1.55	1.91	1.91	1.73	1.73	2.27
	Std. Deviation	1.128	1.128	1.300	1.221	1.009	1.009	.905
60-69	N	10	10	10	10	10	10	10
	Mean	1.80	2.40	3.30	2.30	1.50	1.60	1.40
	Std. Deviation	1.317	1.578	1.252	1.567	1.581	1.350	1.647
>= 70	N	6	6	6	6	6	6	6
	Mean	2.83	3.17	3.33	3.00	2.83	2.83	3.00
	Std. Deviation	.753	.753	.816	1.265	1.169	1.169	1.095
Total	N	100	100	100	100	100	100	100
	Mean	1.04	1.19	1.46	1.29	.99	1.00	1.25
	Std. Deviation	1.247	1.331	1.459	1.358	1.115	1.082	1.533

ECTOCRANIAL AND ENDOCRANIAL CLOSURE OF CORONAL SUTURE

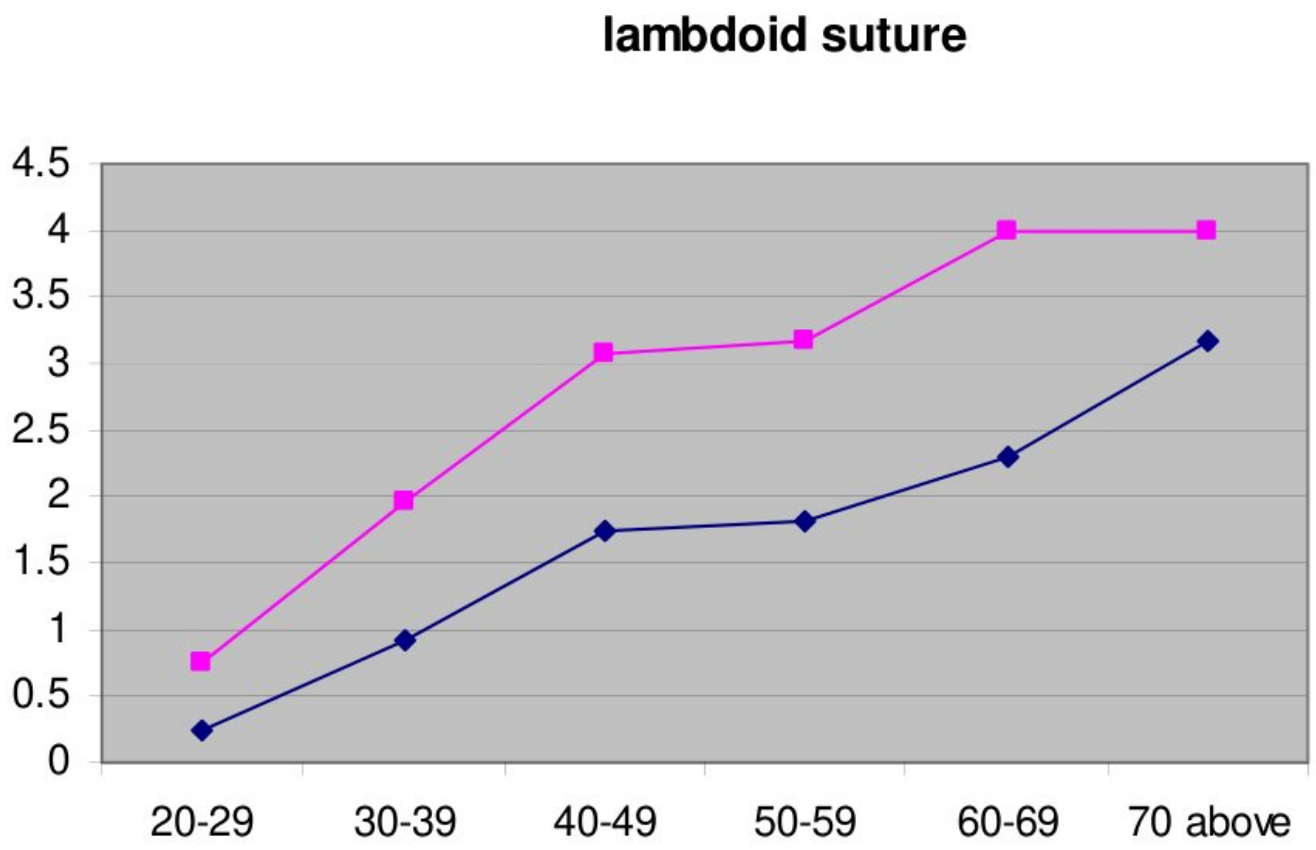


Graph 6

ECTO

ENDO

ECTOCRANIAL AND ENDOCRANIAL CLOSURE OF LAMBDOID SUTURE



Graph 7

ECTO

ENDO

Observation when ectocranial suture closure was taken it is observed that S1 (sagittal suture first part) closure though started it was never complete. Mean value is 0.16 at 20-29 age group and 2.83. (app.3). this n holds good for all the other ectocranial segments. There is no complete closure (value 4) even in more than 70 age group,and the closure is very variable. Within the sagittal suture S3 (pars obelica) appears to fuse much faster (mean value 0.37 at 20-29 age group and 3.33 at more than 70 set), S1 (pars bregmatica) seems to close much slower (0.16 at 20-29 age group to 2.83 at more than 70 years. Total mean value is 1.46 for S3 and 1.04 for S1).

S3 closes earlier followed by S4, S2 and then S1. In coronal suture there is no significant difference between right and left side. Within the coronal suture C1 (pars bregmatica) appears to close slower (0.29 at 20-29 to 2.83 at 70-90 age group) than C3 (pars pterica, 0.42 at 20-29 to 3.00 at 70-90 age group). C3 closes earlier followed by C1 and C2 (mean 1.20, 1.02 and 1.01 respectively). In lambdoid suture L1 (pars lambdica) closes slower (0.18 at 20-29 age group to 3.00 at more than 70 years), L3 (pars asterica) fastest of all (0.34 at 20-29 age group to 3.33 at more than 70 years). L3 closes early followed by L2 and L1 (mean 1.26, 1.06 and 1.01 respectively).(Table 11, 12, 13, 14)

Total closure (mean value > 3.5) never occurred in ectocranial sutures. Mean value for sagittal suture is 3.08; coronal is 2.62 and lambdoid is 3.17 in more than 70 year age group. Lapsed union (persistent non closure) is more pronounced in coronal suture.

When comparison was made between sagittal, coronal and lambdoid suture, overall sagittal suture closes early and then lambdoid, coronal respectively (mean values for 100 cases 1.24, 1.11 and 1.08) But the closure is too erratic to draw conclusion.(graph 5, 6, 7)

Table 12

AGE		ECTO	ECTO	ECTO	ECTO	ECTO	ECTO	ECTO	ECTO	ECTO
GROUP		CL1	CL2	CL3	LR1	LR2	LR3	LL1	LL2	LL3
20-29	N	38	38	38	38	38	38	38	38	38
	Mean	.29	.29	.34	.18	.24	.34	.21	.24	.34
	Std.	.515	.515	.534	.512	.490	.481	.474	.431	.481
						Deviatio				
						n				
30-39	N	25	25	25	25	25	25	25	25	25
	Mean	.92	.88	1.08	.84	.80	1.12	.76	.80	1.04
	Std.	1.038	.971	.997	.898	.866	1.013	.879	.913	.978
						Deviatio				
						n				
40-49	N	10	10	10	10	10	10	10	10	10
	Mean	1.80	1.80	1.80	1.60	1.70	1.90	1.60	1.70	1.90
	Std.	.632	.632	.789	.699	.823	.876	.699	.823	.876
						Deviatio				
						n				
50-59	N	11	11	11	11	11	11	11	11	11
	Mean	1.73	1.82	2.18	1.64	1.64	2.00	1.64	1.64	2.00
	Std.	1.009	1.079	.874	.924	.924	1.095	.924	.924	1.095
						Deviatio				
						n				
60-69	N	10	10	10	10	10	10	10	10	10
	Mean	1.80	1.50	1.60	2.20	2.30	2.50	2.10	2.30	2.50

	Std.	1.476	1.434	1.506	1.317	1.337	1.434	1.449	1.337	1.434
						Deviatio				
						n				
>= 70	N	6	6	6	6	6	6	6	6	6
	Mean	2.83	2.83	3.00	3.00	3.17	3.33	3.00	3.17	3.33
	Std.	1.169	1.169	1.095	.894	.753	.516	.894	.753	.516
						Deviatio				
						n				
Total	N	100	100	100	100	100	100	100	100	100
	Mean	1.06	1.03	1.16	1.02	1.06	1.27	1.00	1.06	1.25
	Std.	1.162	1.141	1.178	1.163	1.179	1.254	1.155	1.179	1.250
						Deviatio				
						n				

Table 13

AGE		**ENDO**	**ENDO**	**ENDO**	**ENDO**	**ENDO**	**ENDO**	**ENDO**
GROUP		S1	S2	S3	S4	CR1	CR2	CR3
20-29	N	38	38	38	38	38	38	38
	Mean	.76	.79	.95	.84	.71	.82	.87
	Std.	.943	.935	1.064	.945	.867	1.010	.935
					Deviation			
30-39	N	25	25	25	25	25	25	25
	Mean	2.20	2.00	2.56	2.36	2.08	2.28	2.20
	Std.	1.414	1.384	1.417	1.604	1.320	1.429	1.384
					Deviation			
40-49	N	10	10	10	10	10	10	10

	Mean	3.10	2.80	3.20	3.30	3.00	3.10	3.10
	Std.	.876	.919	.919	.675	.943	.738	.738
				Deviation				
50-59	N	11	11	11	11	11	11	11
	Mean	2.91	3.00	3.00	3.00	3.55	3.55	3.45
	Std.	1.300	1.183	1.183	1.183	.688	.688	.688
				Deviation				
60-69	N	10	10	10	10	10	10	10
	Mean	3.20	3.50	4.00	3.90	3.60	4.00	3.60
	Std.	1.687	1.269	.000	.316	1.265	.000	1.265
				Deviation				
>= 70	N	6	6	6	6	6	6	6
	Mean	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	Std.	.000	.000	.000	.000	.000	.000	.000
				Deviation				
Total	N	100	100	100	100	100	100	100
	Mean	2.03	2.00	2.29	2.20	2.08	2.22	2.17
	Std.	1.586	1.537	1.565	1.595	1.574	1.586	1.538
				Deviation				

Within endocranial suture there was no difference in closure of sutures on right and left side. (mean values coronal 2.18 vs 2.15 on left side, lambdoid 2.08 on right side and 2.08 on left side). In sagittal suture S3 (pars obelica) closes earlier than other three parts.(graph 10- 13) S3 closes early followed by S4, S1 and S2. (Mean value 2.29, 2.20, 2.03 and 2.00) In coronal suture C2 (pars complicata) closes earlier than C1 and C3 (mean value 2.17, 2.15 and 2.15). In lamdoid suture L3 (pars asterica) closes earlier followed by L2 (pars intermedia) and L1 (pars lambdica).

(Mean value of 2.16, 2.05 and 2.04).

Sagittal suture, endocranially starts fusing at the age of 20 -29 years. More or less complete union >3 is attained at 40-49 age group (mean 3.10, maximum 3.30 for S4).It is totally fused by the age of 60-69 years (mean value 3.65). In coronal suture near complete closure occurs by the age of 40-49 age and total closure occurs by 50-59 years. (Mean value 3.10 in 40-49 years and 3.55 by 50-59 years of age). lambdoid suture starts fusing during 20-29 age group and closes by 40-49 years but the complete closure occurs during 50-59 years age.(mean values 0.76, 3.06 , 3.23 respectively for 20-29, 40-49 and 50-59).

Overall coronal suture closes earlier followed by sagittal and lambdoid suture endocranially.

(Mean values 2.18, 2.13 and 2.10)

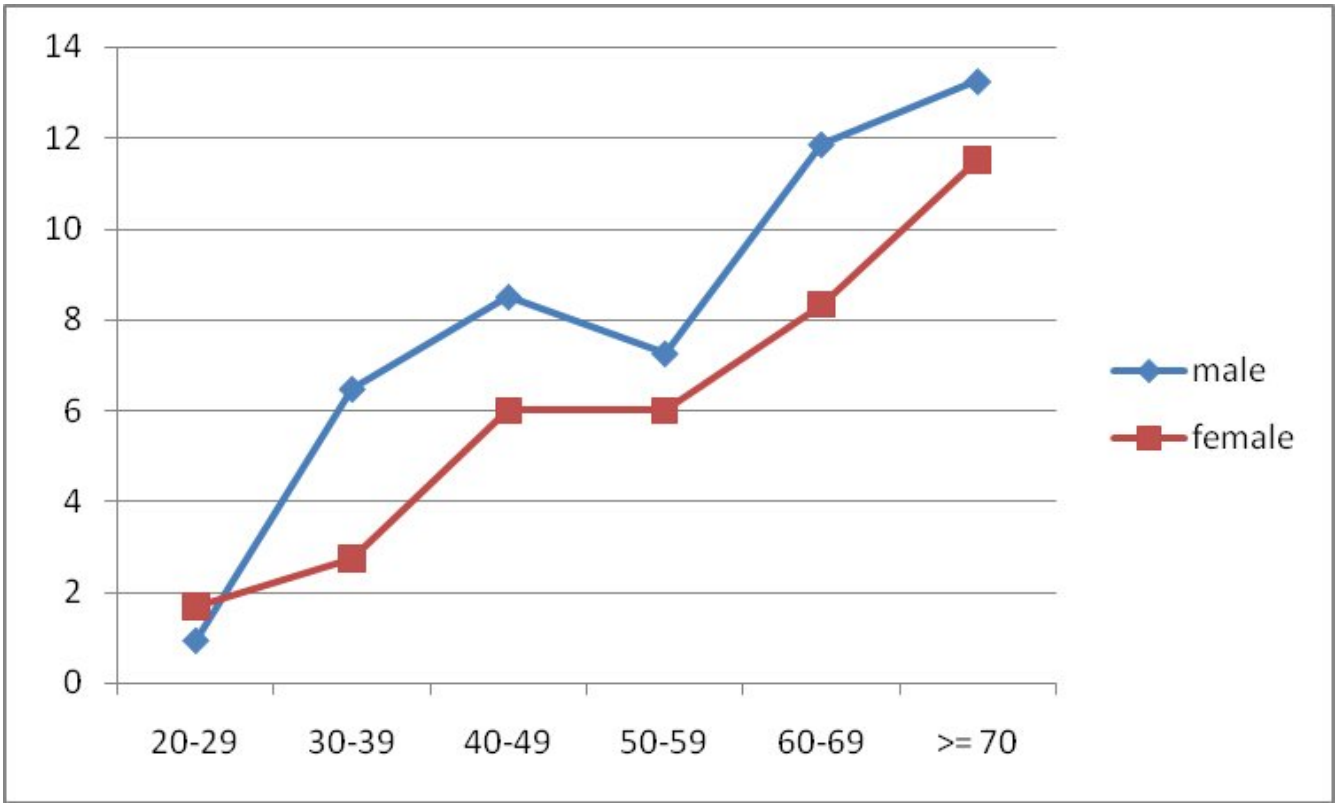
Table 14

AGE		ENDO	ENDO	ENDO	ENDO	ENDO	ENDO	ENDO	ENDO	ENDO
GROUP		CL1	CL2	CL3	LR1	LR2	LR3	LL1	LL2	LL3
20-29	N	38	38	38	38	38	38	38	38	38
	Mean	1.26	.74	.87	.71	.71	.84	.74	.74	.84
	Std.	3.554	.860	.935	.835	.835	.855	.828	.828	.855
						Deviati				
						on				
30-39	N	25	25	25	25	25	25	25	25	25
	Mean	1.84	2.08	2.00	1.96	1.92	2.00	1.96	1.92	2.00
	Std.	1.313	1.441	1.414	1.172	1.222	1.291	1.274	1.222	1.291
						Deviati				
						on				
40-49	N	10	10	10	10	10	10	10	10	10
	Mean	3.00	3.10	3.10	2.80	3.00	3.40	2.80	3.00	3.40
	Std.	.943	.738	.738	.789	.471	.699	.789	.471	.699
						Deviati				
						on				
50-59	N	11	11	11	11	11	11	11	11	11
	Mean	3.36	3.36	3.45	3.18	3.18	3.27	3.18	3.18	3.27
	Std.	.809	.809	.688	1.250	1.250	1.191	1.250	1.250	1.191
						Deviati				
						on				
60-69	N	10	10	10	10	10	10	10	10	10
	Mean	3.60	4.00	3.60	4.00	4.00	4.00	4.00	4.00	4.00

	Std. Deviation	1.265	.000	1.265	.000	.000	.000	.000	.000	.000
>= 70	N	6	6	6	6	6	6	6	6	6
	Mean	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	Std. Deviation	.000	.000	.000	.000	.000	.000	.000	.000	.000
Total	N	100	100	100	100	100	100	100	100	100
	Mean	2.21	2.12	2.12	2.03	2.04	2.16	2.04	2.05	2.16
	Std. Deviation	2.532	1.572	1.546	1.521	1.530	1.542	1.530	1.520	1.542

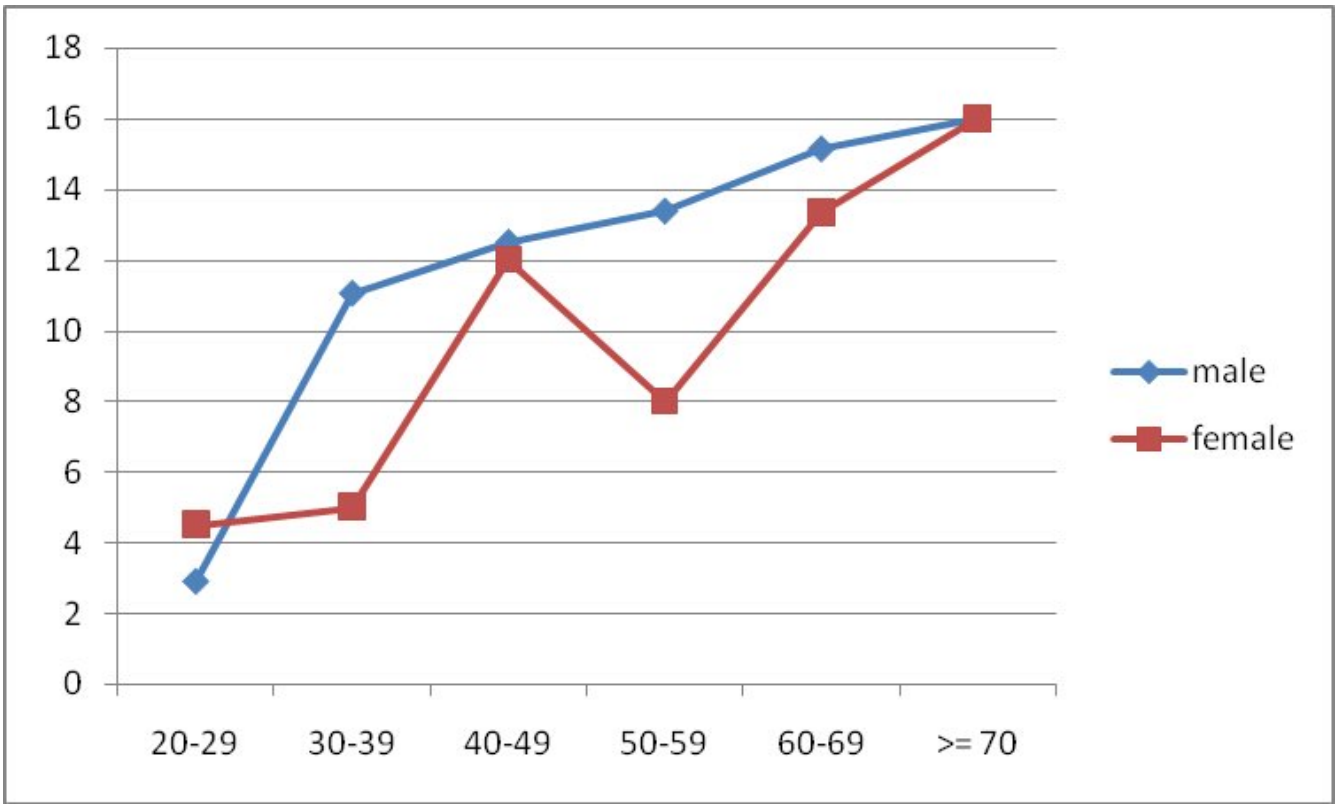
When males to female comparison were made there was no significant correlation (applying Levene's test for equality of variances, p value> 0.05) found. It implies that there is no significant difference in union of sutures in all age groups.(graph 8, 9)

ECTOCRANIAL SAGITTAL SUTURE CLOSRE-SEXUAL VARIATION



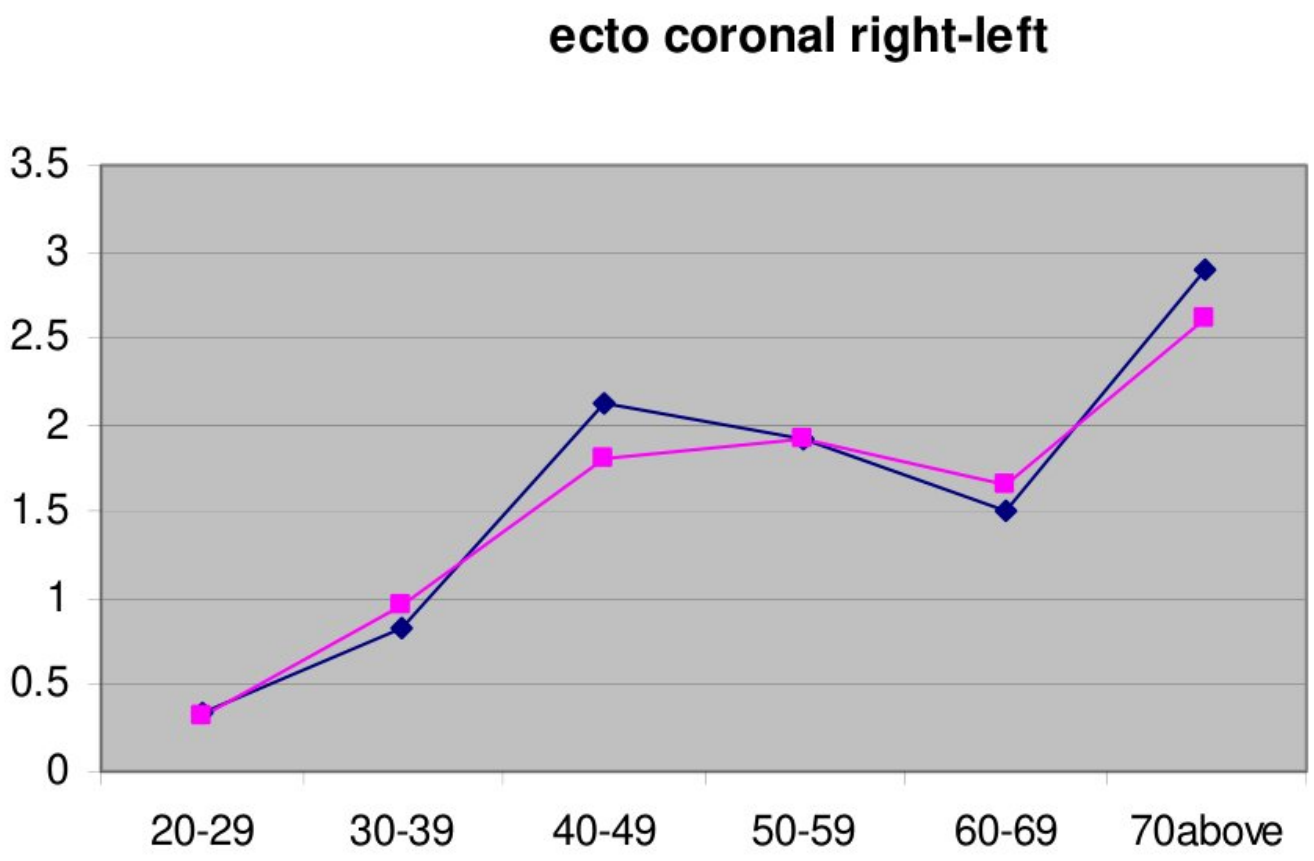
Graph 8

ENDOCRANIAL SAGITTAL SUTURE CLOSRE-SEXUAL VARIATION



Graph 9

BILATERAL VARIATION IN ECTOCORONAL SUTURE

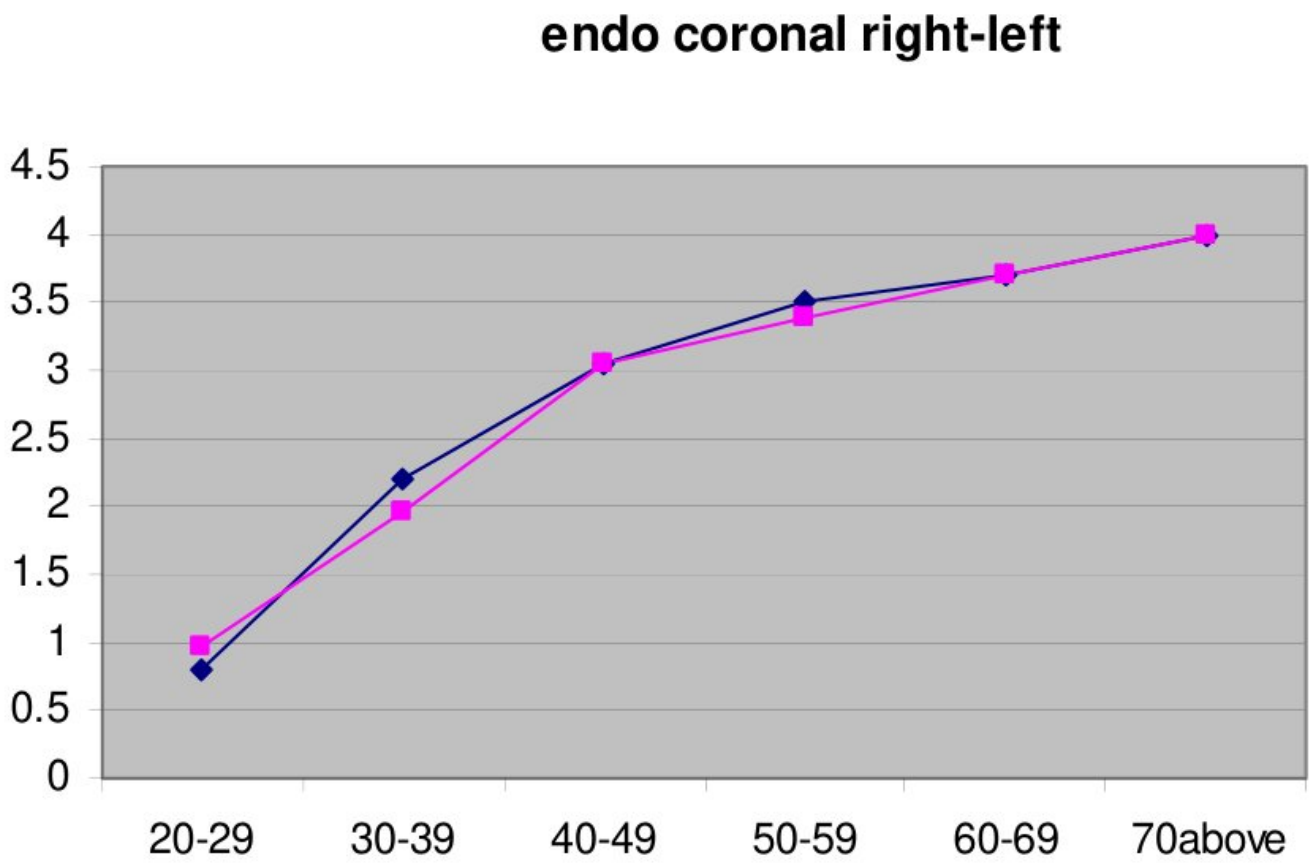


Graph 10

CectoR

CectoL

BILATERAL VARIATION IN ENDOCORONAL SUTURE

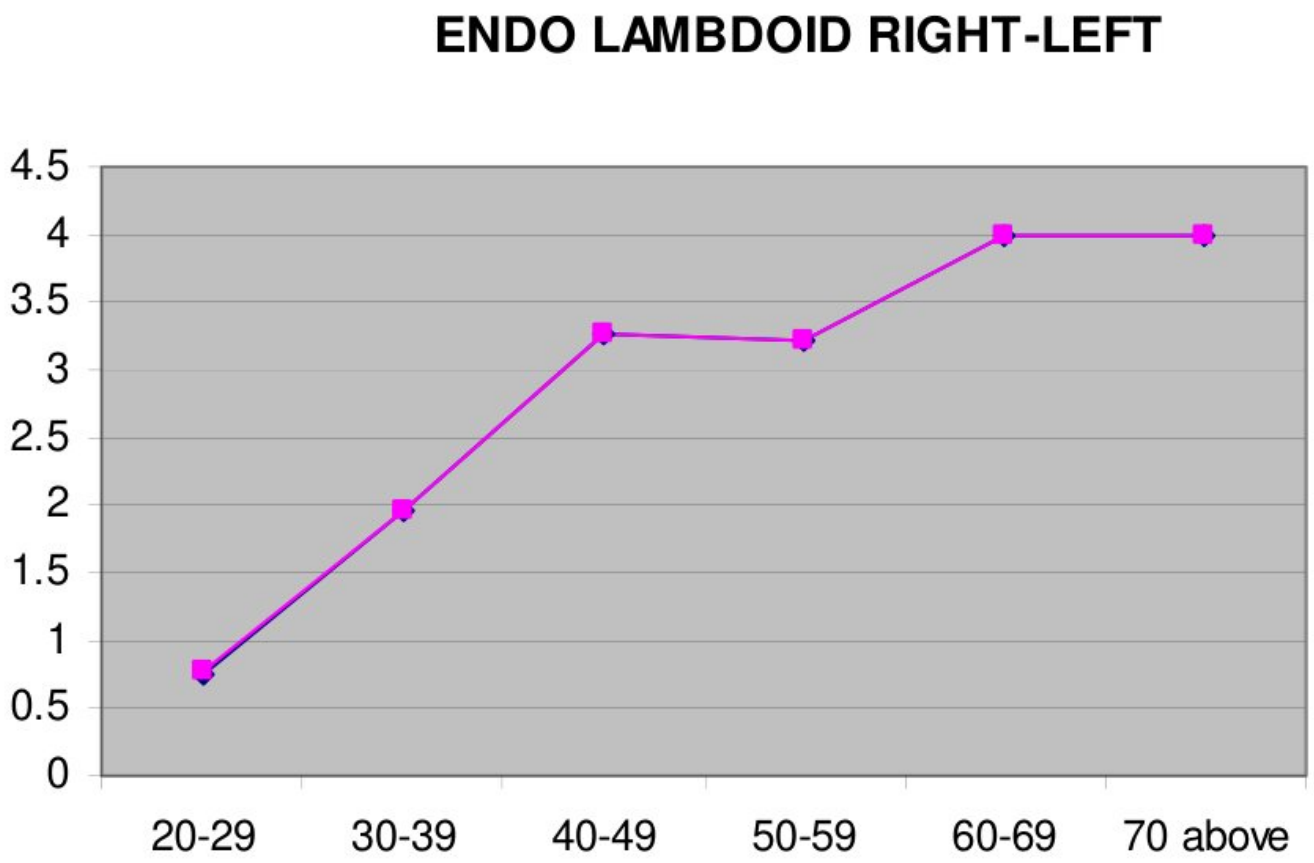


Graph 11

CendoR

CendoL

BILATERAL VARIATION IN ENDOLAMBDOID SUTURE

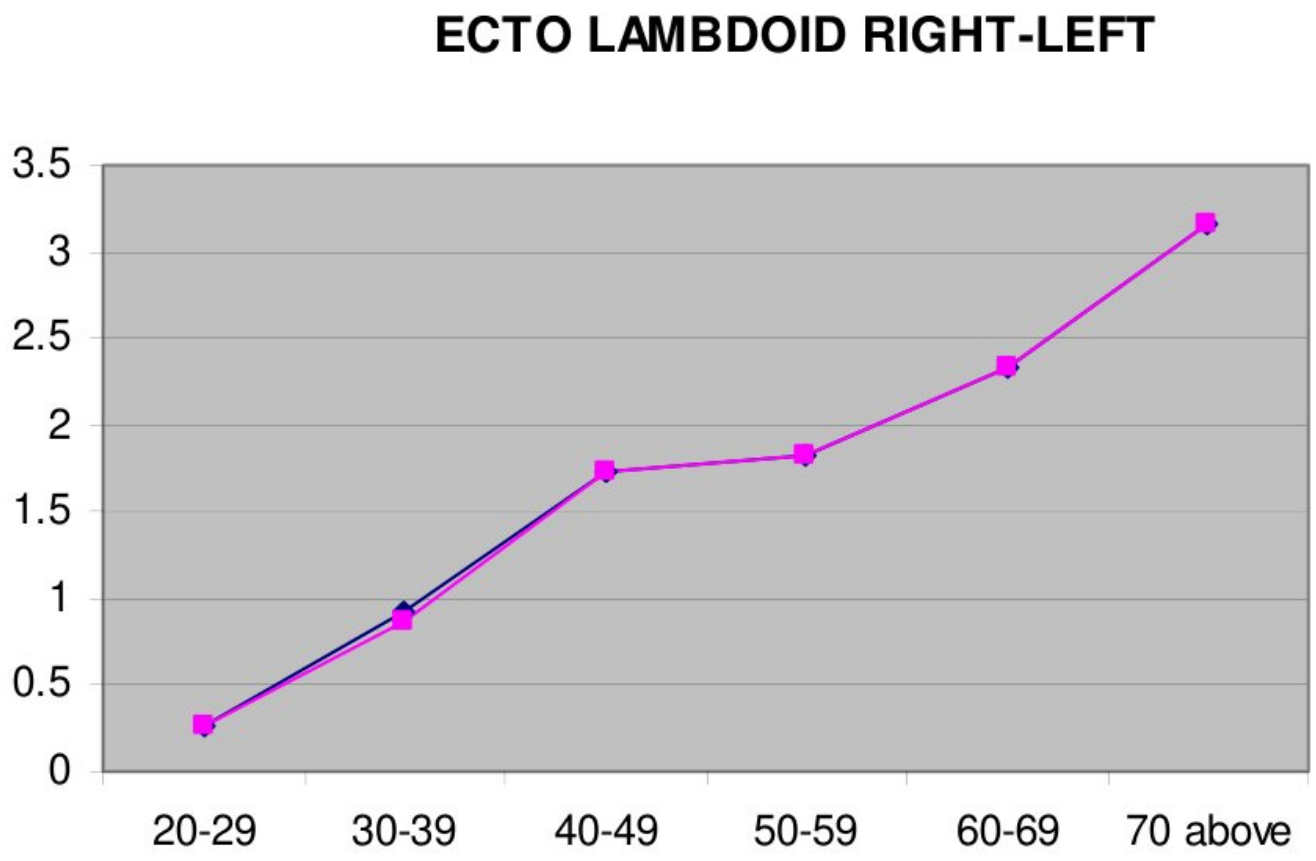


Graph 12

LendoR

LendoL

BILATERAL VARIATION IN ECTOLAMBDOID SUTURE



Graph 13

LectoR

LendoL

Right and left side of coronal and lambdoid sutures were compared both ectocranially and endocranially there were no significant difference after applying student t test (P value>0.05). It implies that there is no bilateral variation in ectocranial and endocranial suture closure.(graph 10 – 13)

DISCUSSION

In later years of life all the teeth have erupted, practically all the epiphyses have united with the diaphysis, the height and weight are of no significance to determine the age.

Gustafson has done the work in which he has given the idea to determine the age on the basis of changes that occur in teeth. Literature is full of certain changes such as lipping of the bones, graying of the hair, appearance of arcus senilis in the cornea, opacity in lens, atherosclerotic changes in the arteries, wrinkling of the skin especially of the face. They are too vague to be considered for determination of age in Medico-legal work.

Obliteration of skull sutures in late age, practically when all the teeth have erupted and epiphysis have fused i.e. after 21 years of age, gives a fairly accurate idea but here also we find that the determination of age can only be in decades, based on sole criterion of suture obliteration.

The fact that the closure is found not to be (positively) correlated with age in individuals who died after fifty need not be a surprise. Many authors have pointed to discrepancies and some have consequently doubted the reliability of suture closure as an age indicator.

However none of these critics abandoned the starting point that if any correlation with age at death existed it had to be a positive one. This is even more noteworthy because in several publications the phenomenon of extremely old individuals with many open sutures is discussed. There are, for example, the crania of four Dutchmen, aged over hundred years, but with open sutures, described by J.B. Davis, and many others like Powers, Bolk. The above results suggest that these aged individuals with open sutures were not merely rare exceptions. There must be some underlying mechanism. The cranium may become thinner, but sutures once closed, do not open again. The question forces itself whether selection does occur. Do individuals with open sutures have more chance to grow old? And if so, to what extent do similar selective mechanisms occur in relation to other age indicators?

Sagittal Suture

In our present study we have found that the sagittal suture, endocranially, starts fusing at the end of 20-29 years and completion is perfected at the age of 60-69 years, and this observation conforms with that reported by Todd & Lyon (1924), while it is in contrast to the observation reported by Pommerol (1869), and Topinard (1885), who indicated endocranial commencement of sagittal suture at a much later age at about 40 years.

These latter workers have reported on very scanty specimens so it can't by considered as authentic. Ectocranially sagittal suture closure was never complete. It implies that lapsed union is a significant problem in ectocranial sutures. Youngest age at which sagittal suture union was seen in 34 years ectocranially and 32 years endocranially.

Coronal

While in the present study endocranial fusion of coronal suture was observed as early as 20-29 years and completion by the age of 60-69 years other workers like Pommerol (1869), Topinard (1885), Ribbe (1885) reported closure between 40-50 years. Their study does not indicate whether it was ecto-cranial or endocranial or it was commencement or termination. Coronal suture showed highest cases of lapsed union. In coronal suture youngest age at which complete union was seen at 60 years ectocranially and 32 years endocranially. While in our study lapsed union was mostly seen in ecto-coronal suture, where as Reddy indicates sagittal suture.

Lambdoid

Lambdoid endocranially, starts fusing at the age of 20-29 years in the present context which shows that it is a year earlier than that reported by Todd and Lyon (1924), while completion in our study is 50-59 years. The other workers have not reported on lambdoid suture. Earliest age at which complete union of lambdoid suture was seen at 52 years ectocranially and 36 years endocranially.

Our Indian data compare well with those of the male whites (Todd & Lyton 1925). Negro skulls however show an earlier date of commencement and closure.

Form the present study (see graphs and tables) it is clearly evident that endocranial union is a far better parameter for age determination than is the ecotocranial union as also has been established by Todd & Lyon (1924 & 1925), Dwight.(25, 28).

All the previous work was done in France, Germany and United States of America, under different climatic conditions and in diverse racial groups. Though consensus of opinion in our country is that the obliteration of the skull sutures in females is some what earlier than that of males, in the present study no substantial difference was noticed. This finding is in conjunction with Meindl and Lovejoy (10).

S. No.	Workers/ Authors			Sagittal	Coronal	Lambdoid
1.	Todd and Lyon(1924)			20-29	26-50	26-31
				20-32	23-25	23-31
2.	Ribbe's (1885)			Closure 21-50 years frequent between 44-45 years Ectocranially sagittal closes first then lambdoid, coronal suture.		
3.	Schmidt (1988)			Closure between 25-40 and completed 40-60 years		
4.	Modi's(1988)			30-50	40-60	50-70
5.	Reddy(1990)(2)			25-35	40	45
6.	Parikh(1990)(35)			30-50	40-60	50-70
7.	Apurba Nandy (1995)(33)			25-45	25-45	27-50
8.	Robert Shapiro and Janzen (1960)			22-35	24-38	26-42
9.	Werner and Fisher's text book			25-40	25	35-45
10.	Vyas P. C. (34)			50-55	45-60	60
				50-55	50-60	60
11.	Moondra A. K. (32)	Endo	m	46-50	46-50	56-60
			f	46-50	56-60	56-60
		Ecto	m	51-55	51-55	Above 60
			f	40-60	56-60	Above 60
12	Present study(2007)	Ecto		>70	Lapsed union	>70
		Endo		60-69	40-49	40-49

Several studies have revealed that in the Indian population, as a rule, the epiphyses fuse with metaphyses earlier than in the western Caucasians (14-18). Precosity in fusion has been described to be from 1 to 2 years (19) and 2-3 years (20). It is, therefore, expected that the same rule should be applicable to skull sutures as well; Mckern and Stewart (21)

examined 369 skulls from the skeletal remains of the American soldiers, between the ages of 17 and 50 years who were killed in North Korean war. They observed that in the youngest age group of 17-18 years containing 55 skulls the incidence of complete or partial obliteration of sutures was sagittal 25%, coronal 1% and lambdoid 8%. Present studies show that in the first age group of 18-20 years in males, the incidence of partial complete closure was sagittal 14%, coronal 16.3% and lambdoid 4.7%. This shows that on the whole the skull sutures do not close earlier in the northwest Indians than in Americans. Some workers in USA and India have shown the epiphyses of the long bones fused with the metaphyses earlier in females than in males (22, 13). However, in case of skull sutures reverse seems to be the case (23, 25). In the present material all the three main sutures of the skull started closing earlier in the males than in the females. Some male skulls with completely obliterated sutures on the both surfaces (4/4 or 3/3) were observed in the first two age groups in males but no such specimen could be located amongst the female skulls.

Todd and Lyon (25, 26) and Hrdlicka's (27) have shown that skull sutures closed earlier on the endocranial surface than the ectocranial. They also found the former to be quite often more reliable as the outer sutures had "lapsed union". Neither did they find any gender difference in closure of suture closure on the two surfaces. Present observations reveal that there is no specific difference in the time of closure of sutures on the two surfaces. "Lapsed union" could be seen on the endocranial surface as well, therefore, it cannot be said that the latter is more reliable than the former.

Topinard (13) made some specific observations regarding estimation of age from the extent of obliteration of skull sutures. According to him, if all the sutures were open, the age of the skull was 35 years or less; if the posterior part of the sagittal suture started closing the age would be about 40 years and if the coronal suture near bregma started closing the age should be 50 years or more. His observations were contradicted by Dwight (28) and Parsons and box (23) who showed that suture closure commenced much earlier. According to Hrdlicka (27) the estimated age from the skull sutures is within 10 years one way or the other from the real age. Dwight (28) examined 100 skulls of paupers whose ages had been recorded. According to him the sutures start closing under 30 years; closing of sutures almost invariably began on the endocranial surface earlier than ectocranially and variability in suture closure was the rule. He, however, dismissed the suggestion that sutures were worthless in indicated the age of a given skull. Todd and Lyon (25, 26) undertook extensive studies on the time of closure of the skull sutures. The examined male skulls of 307 whites and negroes and found that in the former, on the outer surface, the sagittal sutures started to close at the age of 22 years and got completely closed at 35 years, the obliteration of the coronal suture commenced at 26 years and got completed by 42 years; the lambdoid suture showed commencement of closure at 26 years and was completely closed at 42 years. Almost similar results were obtained in case of Negro skulls. They excluded from their study 40 white and 41 black skulls as in those specimens suture closure did not fit a definite trend of progress. Their principal of rejecting "irregular" specimens was criticized by Cobb (24) as this rejection was responsible for the subsequent workers not being able to endorse the observation of Todd and Lyon (25, 26).

Perizonius (11) studies the time of suture closure in 174 male and 82 female skulls of non-Jewish inhabitants of Amsterdam whose ages were between 20 and 99 years. He examined the sutures endocranially by introducing a small lamp through the foramen magnum. He did not find any difference in the time of closure of the sutures in two sexes or on the two surfaces. According to him, the obliteration of sutures was related to age in the age group of 20-49 years but not thereafter. Validity of his observations is questionable as it is not possible to observe the lateral parts of the lambdoid sutures endocranially by the procedure followed by him.

Some workers including Steward (29), Singer (31) Mckern and Stewart (21), Powers (30) have stated unequivocally that suture closure is unreliable as a guide to the age of a skull. Present studies reveal that obliteration of the various segments of the three main sutures of the skull is so erratic that neither does it help in estimating the age of the deceased nor does it provide any supportive evidence in determining the age of skeletal remain.

CONCLUSIONS

The present study we tried the possibilities for suture closure to contribute to one of the essential foundations of Paleodemography: age estimation. There is a need for more detailed studies (different age groups, sub samples, individual suture segments etc..) for a subject like suture closure. It is evident that, before several age indicators are combined into complex methods, as much information as possible about the separate age indicators has to be accumulated. This information can be obtained only by investigating skeletal material of known age. For a better estimation of age not only morphological but also histological age indicators may be used.

There is a limited relationship between suture closures, at least above 40 years of age seem to be dependent on factors other than biological aging, and these factors can dictate fast closure or persisting nonclosure. Our analyses strengthen the view that regardless of scoring method, there is only a very loose association between suture closure and age, and this poses a real problem in terms of practical use for age determination. There is the fundamental problem of using a method based on a structure which as yet is simply poorly understood. But whatever the underlying biological factors are for suture closure, and even if these in the future should be better understood, it is still important to refine the methods of quantifying these structures, in order to render the methods of quantification as unbiased as possible.

1) Ectocranial suture closure cannot be used for age estimation. Lapsed union is a major deterrent for age estimation. It is more pronounced in coronal suture.

2) Suture obliteration starts earlier on endocranial surface than on the ectocranial.

3) There is some correlation between endocranial suture closure and age upto 40-50 year's age group, there after there is no significant correlation. Any attempt to derive a reliable formula to estimate the age from score of suture closure was met with failure for the following reasons: 1) the trend of correlation is neither increasing nor decreasing with age, 2) the sample size is too small to derive a formula 3) unequal distribution of males and females in the study sample.

4) Although cross-sectional in nature, suture obliteration patterns (totally open, totally closed, partially open, and partially closed) are not temporary progressive stages on an age scale, but rather independent permanent phenomena.

5) Though there is some difference in suture closure in males and females, it is not significant statistically. (Females showed earlier union than males in the age group 20-29, in the other age groups suture closure occurred earlier in males).

6) There is some statistically significant correlation between ectocranial and endocranial suture closure upto 40 years of age. They appear to close independently of each other after 40 years.

7) There is no significant variation in suture closure of right and left sides of coronal and lambdoid sutures; both ectocranially and endocranially.

8) Endocranially: coronal suture closes earlier followed by sagittal and lambdoid.

9) Ectocranially: sagittal suture closes earlier followed by lambdoid and coronal.

10) Ectocranially: Within the sagittal suture segments, pars obelica(S3) closes earlier followed by pars lambdica (S4), pars vertices(S2) and pars bregmatica(S1). In coronal suture pars pterica(C3) unites faster followed by pars bregmatica(C1) and pars complicata(C2). In lambdoid suture pars asterica(L3) closes earlier followed by pars intermedia(L2) and pars lambdica(L1).

11) Endocranially: Within sagittal suture segment, pars obelica(S3) closes earlier followed by pars lambdica(S4), pars vertices(S2), pars bregmatica(S1). In the complicata(C2) unites earlier followed by pars coronal suture, pars bregmatica(C1) and pars pterica(C3). In lambdoid suture pars asterica(L3) closes earlier followed by pars intermedia(L2) and pars lambdica(L1).

12) Endocranial union starts 20-29 age groups but progression is not uniform.

Complete closure (mean value > 3.5) of sagittal and coronal sutures occurs in the age group of 60-69 years whereas in the lambdoid it occurs by 50-59 years.

13) Ectocranial union started in the 20-29 age group, but it's progression is very erratic. Complete closure (mean value > 3.5) never occurred in ectocranial sutures. Maximum closure occurred in the above 70 years age group with mean values of 2.62, 3.08, and 3.17 for coronal, sagittal, lambdoid suture respectively.

14) Metopism was observed in 3% of cases.

15) Commencement and complete obliteration of a segment or the entire suture is so erratic that it is not amenable for estimating the age.

RECOMMENDATIONS

1. In present study, persons between the ages of <20 and >90 years for closure of suture are not taken, so to find good results, these groups should be included.

2. Sutures like basilar suture and metopic suture, lateral sutures, palatal sutures etc.

should be included.

3. As in present study difference between each age group is 10 years and so it should be reduced to get better results.

4. In order to have a more accurate and better assessment of suture closure various other modalities like radiology (x-ray, CT scan, MRI), histology may have to be combined.

5. In our study age (38% of cases in 20-29 age group) distribution and sex (72% males) is not uniform. Hence, this (sampling error) has to be taken into consideration in future studies.

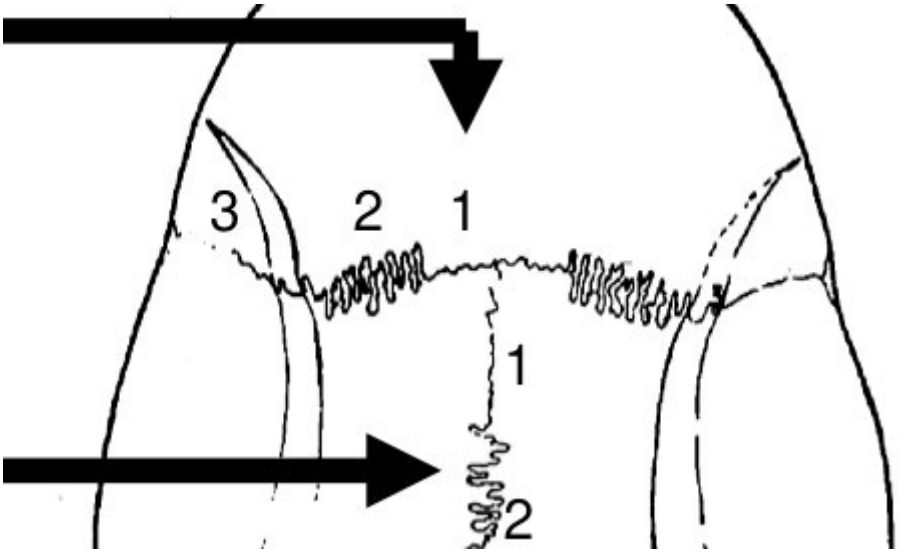
6. In present study there are only 100 cases which may not be the representation of whole population. Hence the study population (sample size) has to be increased in future studies.

7. Age estimation from morphological changes in bone has always been a matter of debate as it is very erratic and affected by various factors such as climatic, dietetic, hereditary, nutritional, sociological, racial, environmental, geographical etc. Cranial sutures are no exception to that. So, much study is needed in estimation of age from cranial sutures.

C

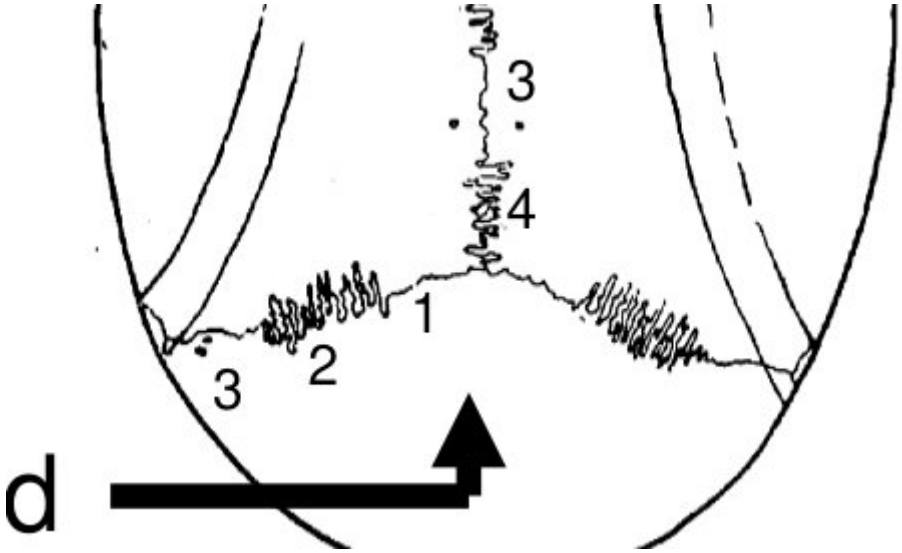
Coronal l

• Coronal 1. pars bregmatica p g



Sagittal 2. pars complicata 3. pars pterica

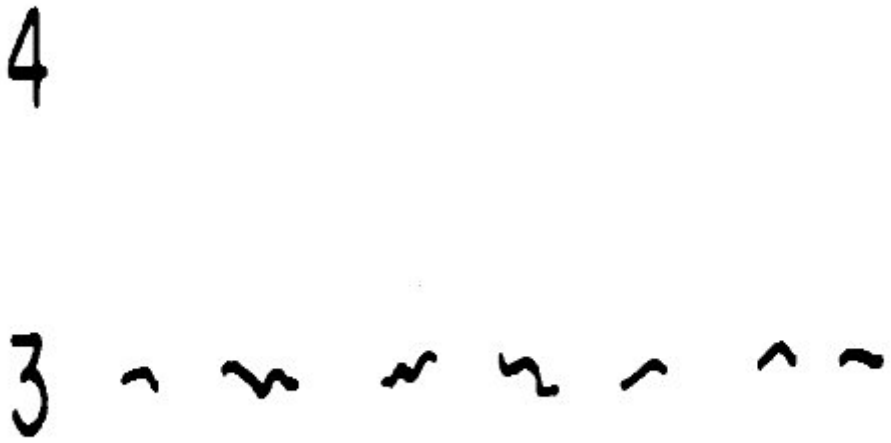
•Sagittal 1. pars bregmatica 2 pars verticis 2. pars verticis

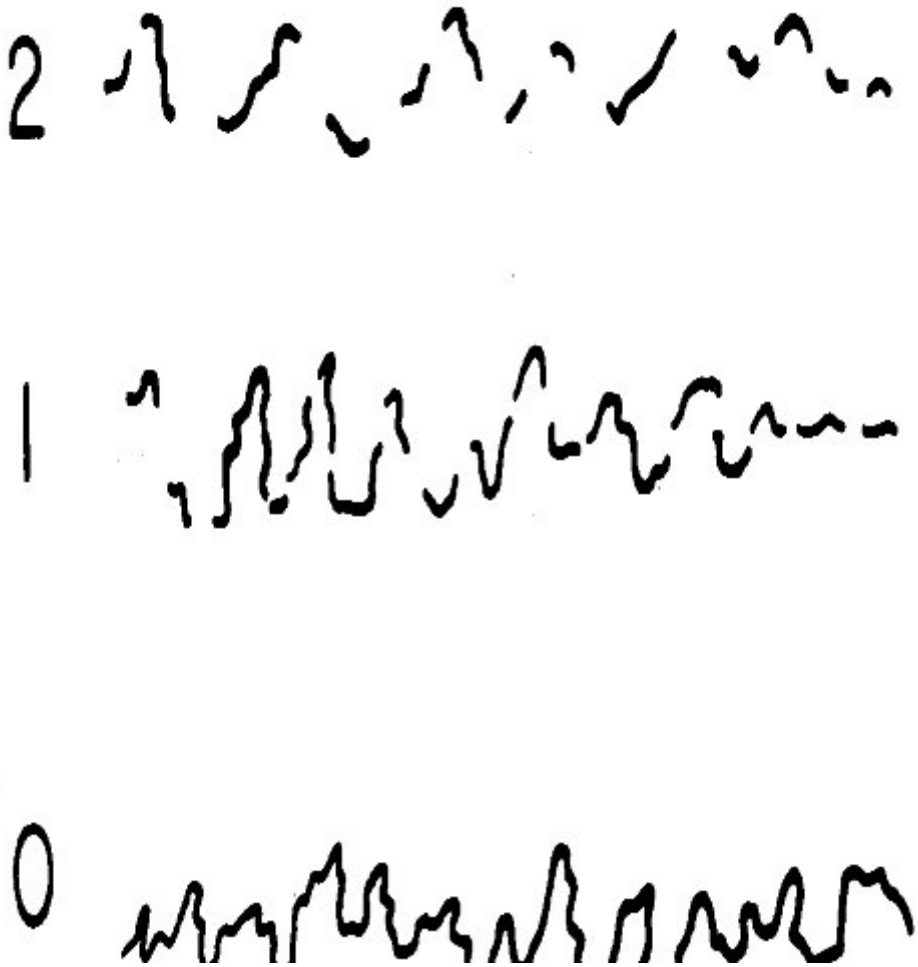


Lambdoid 3. pars obelica 4. pars lambdica

• Lambdoid 1. pars lambdica 2 pars intermedia 2. pars intermedia 3. pars asterica

Ectocranial sutures





Scoring system

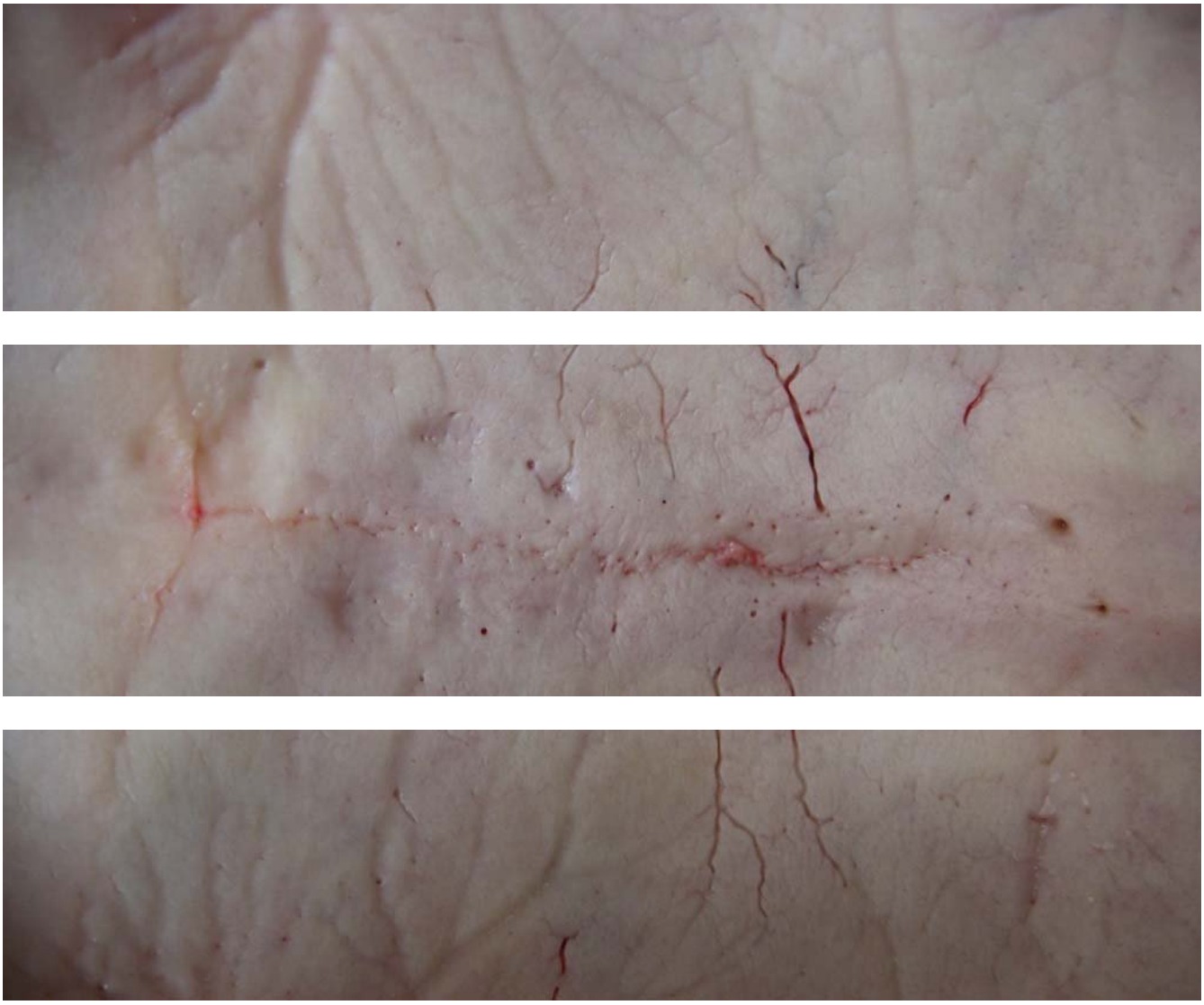




Skull of 27 year old female showing score of 1 in ectocranial surface of lambdoid suture (PM No. 377/07)

(

)



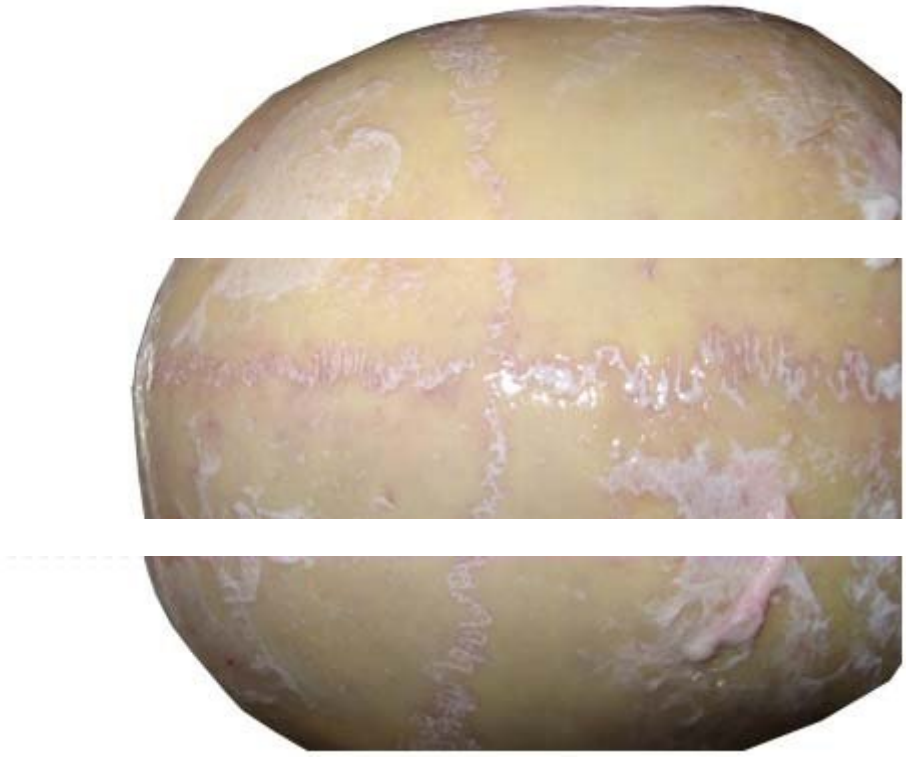
Skull of 27 year old female showing score of 3 in S u o yea o d e a e s o g sco e o 3 endocranial surface of sagittal suture (PM No. 377/07)



Skull of 27 year old female showing score of 2 in ectocranial surface of coronal suture (PM No. 377/07)

(

)



Metopism as seen in 48 year old male p y

Skull. (PM No. 789/07)

KEY WORDS

S	SAGITTAL
C	CORONAL
L	LAMBDOID
R	RIGHT
L	LEFT
ENDO	ENDOCRANIAL
ECTO	ECTOCRANIAL
S1	PARS BREGMATICA
S2	PARS VERTICES
S3	PARS OBELICA
S4	PARS LAMBDICA
C1	PARS BREGMATICA
C2	PARS COMPLICATA
C3	PARS PTERICA
L1	PARS LAMBDICA
L2	PARS INTERMEDIA
L3	PARS ASTERICA
m	MALE
f	FEMALE
r	CORRELATION COEFFICIENT
t-test	STUDENT'S T TEST

SUMMARY

Introduction

External inspection of the dead permits only an approximate estimation of age.

Age, however, is a primary characteristic in the identification and its estimation is of considerable importance. The skeleton and the teeth are the principal sources of information towards the age estimation. Determination of age becomes progressively more difficult as the age advances, particularly after the age of 20-25 years. Scientific estimation of age of an individual from human remains is a vexing problem for medical jurist in both civil and criminal matters.

Aim

The main objective of the study was to observe the chronology and pattern of closure of cranial sutures. In this study, we also tried to explore the feasibility of using cranial sutures for age estimation.

Methodology

This study was conducted in the Department of Forensic Medicine, Maulana Azad Medical College on dead bodies coming for medicolegal post-mortem examination, during the period of January 2007 to March 2008. Coronal, sagittal and lambdoid sutures of 100 subjects over the age of twenty years were studied. Acsadi and Nemeskeri method was applied to both endo and ectocranial sides of the sutures. Unknown and unclaimed bodies were not taken because of difficulty in knowing the age. Cases showing deformed or diseased or fractured skull were also excluded from study (which may hamper the sutural integrity).

Photographs were taken in every case.

A predesigned proforma was filled up for every case, master chart was prepared. Cases were stratified into 10 year groups. The results obtained after statistical analysis were analysed and compared with the works of previous authors.

CONCLUSIONS

1) Ectocranial suture closure cannot be used for age estimation. Lapsed union is a major deterrent for age estimation. It is more pronounced in coronal suture.

2) Suture obliteration starts earlier on endocranial surface than on the ectocranial.

3) There is some correlation between endocranial suture closure and age upto 40-50 year's age group, there after there is no significant correlation. Any attempt to derive a reliable formula to estimate the age from score of suture closure was met with failure for the following reasons: 1) the trend of correlation is neither increasing nor decreasing with age, 2) the sample size is too small to derive a formula 3) unequal distribution of males and females in the study sample.

4) Although cross-sectional in nature, suture obliteration patterns (totally open, totally closed, partially open, and partially closed) are not temporary progressive stages on an age scale, but rather independent permanent phenomena.

5) Though there is some difference in suture closure in males and females, it is not significant statistically. (Females showed earlier union than males in the age group 20-29, in the other age groups suture closure occurred earlier in males).

6) There is some statistically significant correlation between ectocranial and endocranial suture closure upto 40 years of age. They appear to close independently of each other after 40 years.

7) There is no significant variation in suture closure of right and left sides of coronal and lambdoid sutures; both ectocranially and endocranially.

8) Endocranially: coronal suture closes earlier followed by sagittal and lambdoid.

9) Ectocranially: sagittal suture closes earlier followed by lambdoid and coronal.

10) Ectocranially: Within the sagittal suture segments, pars obelica(S3) closes earlier followed by pars lambdica (S4), pars vertices(S2) and pars bregmatica(S1). In coronal suture pars pterica(C3) unites faster followed by pars bregmatica(C1) and pars complicata(C2). In lambdoid suture pars asterica(L3) closes earlier followed by pars intermedia(L2) and pars lambdica(L1).

11) Endocranially: Within sagittal suture segment, pars obelica(S3) closes earlier followed by pars lambdica(S4), pars vertices(S2), pars bregmatica(S1). In the coronal suture, pars complicata(C2) unites earlier followed by pars bregmatica(C1) and pars pterica(C3). In lambdoid suture pars asterica(L3) closes earlier followed by pars intermedia(L2) and pars lambdica(L1).

12) Endocranial union starts 20-29 age groups but progression is not uniform. Complete closure (mean value > 3.5) of sagittal and coronal sutures occurs in the age group of 60-69 years whereas in the lambdoid it occurs by 50-59 years.

13) Ectocranial union started in the 20-29 age group, but it's progression is very erratic.

Complete closure (mean value > 3.5) never occurred in ectocranial sutures. Maximum closure occurred in the above 70 years age group with mean values of 2.62, 3.08, and 3.17 for coronal, sagittal, lambdoid suture respectively.

14) Metopism was observed in 3% of cases.

15) Commencement and complete obliteration of a segment or the entire suture is so erratic that it is not amenable for estimating the age.

RECOMMENDATIONS

1. In present study, persons between the ages of <20 and >90 years for closure of suture are not taken, so to find good results, these groups should be included.

2. Sutures like basilar suture and metopic suture, lateral sutures, palatal sutures etc.

should be included.

3. As in present study difference between each age group is 10 years and so it should be reduced to get better results.

4. In order to have a more accurate and better assessment of suture closure various other modalities like radiology (x-ray, CT scan, MRI), histology may have to be combined.

5. In our study age (38% of cases in 20-29 age group) distribution and sex (72% males) is not uniform. Hence, this (sampling error) has to be taken into consideration in future studies.

6. In present study there are only 100 cases which may not be the representation of whole population. Hence the study population (sample size) has to be increased in future studies.

7. Age estimation from morphological changes in bone has always been a matter of debate as it is very erratic and affected by various factors such as climatic, dietetic, hereditary, nutritional, sociological, racial, environmental, geographical etc. Cranial sutures are no exception to that. So, much study is needed in estimation of age from cranial sutures.

	suture formula- ECTO	suture formula- ENDO	
PM no	sex age S1 S2 S3 S4 CR1 CR2 CR3 CL1 CL2 CL3 LR1 LR2 LR3 LL1 LL2 LL3	S1 S2 S3 S4 CR1 CR2 CR3 CL1 CL2 CL3 LR1 LR2 LR3 LL1 LL2 LL3	
663/07	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
308/07	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
99/08	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
175/08	f 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
79/08	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
624/07	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
351/07	m 20 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
423/07	m 20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
857/07	m 21 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
753/07	m 22 0 1 1 1 0 0 0 0 0 0 0 1 0 0 1	2 2 2 2	1 1 2 1 1 2 1 1 2 1 1 2
723/07	f 22 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1
677/07	f 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
74/08	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
211/07	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
588/07	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 0 0	0 0 1 0 0 1 0 0 1 0 0 1
441/07	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 1 1	1 1 1 1 1 1 0 0 1 0 0 1
394/07	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
355/07	m 22 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
753/07	m 22 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2
689/07	f 23 0 0 1 1 1 0 0 1 0 0 1 1 1 1 1 1	2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2
781/07	m 23 0 0 0 0 1 1 1 1 1 1 0 0 1 0 0 1	0 1 1 1	0 0 1 0 0 1 0 0 1 1 1 1
269/07	f 23 0 0 1 1 0 0 0 0 0 0 0 0 1 0 0 0	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1
436/07	m 24 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1
327/07	f 25 0 0 1 1 0 0 1 0 0 1 0 0 1 0 0 1	1 1 1 1	1 1 2 1 1 2 2 2 2 2 2 2
389/07	m 25 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 1	2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2
437/07	m 25 0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 1	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1
587/07	m 25 0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0	0 0 0 0	0 1 1 1 1 1 1 1 1 1 1 1
804/07	f 25 1 1 1 0 0 0 0 0 0 0 1 0 0 1 0	0 0 0 0	0 0 1 1 0 1 1 1 1 1 1 1
672/07	m 25 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 1 1	0 0 0 0 0 0 0 0 0 0 0 0
535/07	m 25 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 0 2 2	0 0 0 0 0 0 0 0 0 0 0 0

752/07	f 26 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 0	2 2 2 2	2 2 2 22 2 2 2 2 2 2 2
79/08	m 26 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	3 3 3 3	3 3 3 3 3 3 2 2 2 2 2
377/07	f 27 1 1 1 1 2 2 2 2 2 2 1 1 2 1 1	3 3 3 3	1 1 1 1 1 1 2 2 2 2 2
590/07	f 27 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0	0 1 4 0	1 4 0 0 1 0 0 0 0 0 0
794/07	m 27 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1
171/08	m 28 1 1 1 1 1 1 1 1 1 1 0 0 1 0 0 1	2 2 2 2	2 2 2 2 2 2 2 2 2 2 2
818/07	m 28 1 2 2 1 1 1 2 1 1 1 2 2 1 1 1 1	2 2 2 2	2 2 3 2 2 3 2 2 2 2 2
801/07	m 28 0 0 1 1 1 1 1 1 1 1 0 1 1 1 1 1	1 1 1 1	2 2 2 2 2 2 1 1 2 1 1 2
631/07	m 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
609/07	f 30 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
350/07	m 30 1 1 1 1 2 2 2 2 2 2 2 2 3 2 2 3	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
346/07	m 31 2 2 1 1 0 0 0 0 0 0 2 1 3 0 0 0	2 1 3 0	2 0 0 0 0 0 0 0 0 0 0 0
347/07	m 31 2 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0	2 1 4 0	0 0 0 0 0 0 1 0 0 0 0 0
398/07	m 31 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
887/07	f 32 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2	2 2 2 2	2 2 3 2 3 3 2 2 2 2 2
531/07	m 32 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	3 3 3 3	2 2 3 2 2 3 3 3 3 3 3
172/08	m 32 0 2 3 2 2 2 2 3 3 3 2 2 2 2 2 2	2 1 4 4	2 3 3 3 3 3 3 3 3 4 3 3
654/07	m 32 1 2 3 1 2 2 2 3 2 2 0 0 1 0 0 1	1 0 4 4	4 4 4 2 2 2 2 2 3 2 2 3
703/07	f 32 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
373/07	m 34 4 4 4 4 4 2 2 2 2 2 2 2 2 2 2 2	4 4 4 4	3 3 3 3 2 2 2 2 2 2 2 2
584/07	f 35 2 2 2 2 1 1 2 1 1 2 1 1 2 1 1 2	2 2 3 3	3 3 3 3 3 3 3 3 3 3 3 3
566/07	m 35 1 1 1 1 0 0 1 0 0 1 0 0 1 0 0 1	2 2 2 3	2 2 3 2 2 2 3 3 3 3 3 3
655/07	m 35 0 1 4 4 1 1 1 3 3 3 3 3 3 3 3 3	4 3 4 4	3 4 4 3 4 4 2 2 2 2 2 2
429/07	m 35 0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 1	2 2 2 3	3 3 3 3 3 3 3 3 3 3 3 3
87/07	f 35 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0	0 1 1 0	1 3 3 0 0 0 1 1 1 1 1 1
803/07	m 35 1 1 1 1 1 1 2 1 1 2 1 1 1 1 1 1	2 2 2 3	3 3 3 3 3 3 3 3 3 3 3 3
158/07	m 35 1 1 1 1 1 1 2 1 1 2 0 0 0 0 0 0	4 4 4 4	4 4 2 4 4 2 2 2 2 2 2 2
659/07	m 35 1 1 2 0 1 1 1 1 1 1 1 1 1 1 1 1	4 4 4 4	4 4 2 2 4 4 2 2 2 2 2 2
291/07	m 35 4 4 4 4 0 0 0 0 0 0 1 1 1 1 1 1	4 4 4 4	1 3 1 1 3 1 3 3 3 3 3 3
833/07	f 36 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0
243/07	m 36 2 2 4 3 0 1 0 1 1 1 1 1 2 1 1 2	4 3 3 3	2 2 3 2 2 3 3 3 4 3 3 4
298/07	f 37 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0	2 2 2 2	2 3 3 2 3 3 2 2 2 2 2 2
340/07	f 37 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3

371/07	f 40 2 2 2 2 2 2 3 2 2 3 2 2 3 2 2 3	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
625/07	m 40 3 3 2 3 2 2 3 2 2 3 3 3 3 3 3 3	4 4 4 4	4 4 3 4 4 3 3 3 4 3 3 4
460/07	m 41 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 4 4 4	3 3 4 3 3 4 3 3 4 3 3 4
691/07	m 45 4 4 4 4 4 2 1 2 1 2 1 1 1 1 1 1 1	4 2 4 4	2 2 2 2 2 2 2 3 3 2 3 3
388/07	m 45 4 4 4 4 4 2 1 1 2 1 1 1 1 1 1 1 1	4 2 4 4	4 4 4 4 4 4 4 4 4 4 4 4
724/07	m 45 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 2	1 2 2 1 2 2 1 2 2 1 2 2
408/07	m 45 2 2 2 2 1 2 2 2 2 2 1 1 2 1 1 2	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
407/07	m 46 1 1 1 1 3 3 2 3 3 2 2 3 3 2 3 3	3 3 3 3	3 3 3 3 3 3 3 3 4 3 3 4
676/07	f 47 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
789/07	m 48 0 0 1 1 1 1 11 1 1 1 1 1 1 1 1 1	3 3 3 3	4 4 4 4 4 4 3 3 4 3 3 4
790/07	m 50 2 2 3 3 3 3 3 3 3 3 1 1 2 1 1 2	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
455/07	m 50 0 0 0 1 0 0 1 0 0 1 1 1 2 1 1 2	1 2 2 2	2 2 3 2 2 3 2 2 3 2 2 3
88/07	f 50 0 0 0 0 2 2 3 2 3 3 0 0 0 0 0 0	0 0 0 0	4 4 2 2 2 2 0 0 0 0 0 0
559/07	m 50 1 1 1 1 2 2 2 2 2 2 1 1 1 1 1 1	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
168/07	m 50 1 1 1 1 0 0 1 0 0 1 2 2 2 2 2 2	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
700/07	f 52 1 1 2 1 1 1 1 1 1 1 2 2 3 2 2 3	3 3 3 3	3 3 3 3 3 3 3 3 3 3 3 3
430/07	f 52 3 3 3 3 2 2 3 2 2 3 3 3 4 3 3 4	3 3 3 3	4 4 4 4 4 4 4 4 4 4 4 4
177/08	m 55 2 2 2 2 2 2 3 2 2 3 2 2 2 2 2 2	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
576/07	m 55 1 1 2 2 2 2 2 2 2 2 1 1 1 1 1 1	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
772/07	m 55 3 3 4 4 3 3 3 3 3 3 3 3 3 3 3 3	3 3 3 3	4 4 4 4 4 4 4 4 4 4 4 4
168/08	m 56 3 3 3 3 2 2 3 2 2 2 2 2 2 2 2 2	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
471/07	m 60 3 4 4 4 4 4 4 4 4 4 3 3 4 3 3 4	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
816/07	f 60 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
75/08	m 60 3 3 3 3 2 2 3 2 2 3 2 2 3 2 2 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
103/08	f 61 0 0 4 2 0 0 0 0 0 0 0 0 0 0 0 0	0 0 4 4	0 4 0 0 4 0 4 4 4 4 4 4
131/08	m 62 2 3 4 4 2 1 1 2 1 1 2 2 2 2 2 2	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
107/08	m 65 0 1 4 3 0 1 0 0 0 0 3 3 3 3 3 3	0 3 4 3	4 4 4 4 4 4 4 4 4 4 4 4
104/08	m 65 2 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
124/08	m 67 1 2 4 0 2 1 1 3 1 1 4 4 4 4 4 4	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
180/08	f 67 1 0 0 0 0 1 0 1 1 1 1 1 1 0 1 1	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
159/08	m 68 2 3 3 1 0 1 0 1 1 1 2 3 3 2 3 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
472/07	m 70 3 3 4 4 3 3 3 3 3 3 3 3 3 3 3 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
328/07	f 70 2 3 3 1 1 1 1 1 1 1 2 3 3 2 3 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4

472/07	m 70 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
827/07	m 70 2 2 2 2 2 2 3 2 2 3 2 2 3 2 2 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
36/08	F 90 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4
126/07	M 90 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	4 4 4 4	4 4 4 4 4 4 4 4 4 4 4 4

References

1. **1.** Vij K.Identification.In: Textbook of Forensic Medicine and Toxicology Principles and Practises. Elsevier; 2005. P.50-63.
2. **2.** Reddy KSN. Identification. In: The Essentials of Forensic Medicine and Toxicology. K Sugna Devi; 2005. P.67-68.
3. **3.** Buchner A. The identification of human remains. Int. Dent. J. 1985 dec; 35(4): 307- 311.
4. **4.** Knight Bernard .The establishment of identity of human remains. In: Forensic Pathology. Arnold Publication; 1996 .p.121-122.
5. **5.** Galera V, Ubelaker DH, Hayek LA. Comparison of macroscopic cranial methods of age estimation applied to skeletons from the Terry collection. J. Forensic Sci. 1998 Sep; 43(5) : 933-9
6. **6.** Sahni D, Jit I, Neelam , Sanjeev. Time of closure of cranial sutures in North-West Indian adults. Forensic Sci. Int. 2005 Mar 10; 148(2-3): 199-205.
7. **7.** Bednarek J, Bloch-Boguslawska E, Engelgardt P, Wolska E, Sliwka K . The degree of closure of cranial sutures as a quick method for adult age evaluation in autopsy. Arch. Med. Sadowej Kryminol. 2005 Jul-Sep; 55(3): 185-9.
8. **8.** Bednarek J, Engelgardt P, Bloch-Boguslawska E, Sliwka K. Using Lamendin and Meindl-Lovejoy methods for age at death estimation of the unknown person. Arch. Med. Sadowej Kryminol. 2002 Jul-Sep; 52(3): 221-7.
9. **9.** Hershkowitz I, Latimer B ,Dutour O,Jellema L M, Wish-Bartaz S, Rothschild C,et al. Why do we fail in aging the skull from the sagittal suture? .Am. J. Phys. Anthropol. 1997 Jul; 103(3): 393-9.
10. **10.** Meindl RS, Lovejoy CO. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral anterior sutures. Am J Phys Anthropol. 1985 Sep; 68(1):57-66.
11. **11.** Perzonius WRK. Closing and non-closing sutures in 256 crania of known age and sex from Amsterdam (AD 1883-1909). J Human Evolution. 1984; 13: 201-216.
12. **12.** Acsady G, Nemeskeri J. History of human life span and mortality. Akademiai Kiado. 1970.
13. **13.** Krogman WM, Iscan MY.Skeletal age:cranium.In: The Human skeleton in Forensic Medicine.Charles C Thomas Publishers 1986; 2nd edn : p.103-132.
14. **14.** S.M.Hepworth.On determination of age in Indians: Study of ossification of the epiphysis of the long bones.Ind.Med.Gaz.1929; 64:128.
15. **15.** G.Galstaun.Some notes on the union of epiphyses in Indian girls. Ind.Med.Gaz.1930;65:191-192
16. **16.** G.Galstaun.A study of ossification as observsed in Indian subjects.Ind.J.Med.Res.1937; 25:267-324.
17. **17.** R.Lall, B.S.Nat. Ages of epiphyseal union at the elbow and wrist joints amongst Indians. Ind.J.Med.Res.1934; 21:683-689.

18. **18.** D.Narayan, I.D.Bajaj. Ages of epiphyseal union in long bones of inferior extremity in U.P.subjects. Ind.J.Med.Res.1957; 45:645-649.
19. **19.** I.D.Bajaj, O.P.Bhardwaj, S. Bhardwaj. Appearance and fusion of important ossification centres: a study in Delhi population. Ind.J.Med.Res.1967; 55:1064-1067.
20. **20.** M.J.S.Pillai. The study of epiphyseal union for determining the age of south Indians. Ind.J.Med.Res.1936; 23:1015-1017.
21. **21.** T.W.Mckern, T.D. Stewart. Skeletal age changes in young American males: Environmental Protection Research Division, Technical Report EP-45, Headquarters Quartermaster Research and Development Command, Natrick, MA.1957; 26-28.
22. **22.** F.E.Johnston. Sequence of epiphyseal union in a prehistoric Kentucky population.Indian Knoll.Hum.Biol.1961; 33:66-81.
23. **23.** F.G.Parsons, C.R. Box. The relation of cranial sutures to age. J.Anthropol.Inst.Lond. 1905; 35:30-38.
24. **24.** W.M.Cobb. Skeleton in.A.I. Lansing (Ed). Cowdry's problem of ageing, biological and medical aspects. Williams and Wilkins, Baltimore.1952;804.
25. **25.** T.W. Todd, D.W.Lyon jr. Endocranial suture closure. Its progress and age relationship part1.Adult males of white stock. Am. J.Phys.Anthropol.1924; 7:325- 384.
26. **26.** T.W. Todd, D.W.Lyon jr. Suture closure-Its progress and age relationship part4. Ectocranial closure in Adult males of Negro stock. Am. J.Phys.Anthropol.1925; 8:149-168.
27. **27.** A.Hardlicka. Estimation of age in;T.D.Stewart (Ed). Hardlicka's Practical Anthropometry, 4th ed. Wistar Institute of Anatomy and Biology. Philadelphia.1952:54.
28. **28.** T. Dwight. The closure of the cranial sutures as a sign of age. Boston Med. Surg.J. 1890; 122:389-392.
29. **29.** T.D.Stewart. Sequence of epiphyseal union suture closure in Eskimo and American Indians. Am.J.Phys.Anthropol.1934; 19:433-452.
30. **30.** R.Powers. The disparity between known age and sex as estimated by cranial suture closure. 1962; 84:52-54.
31. **31.** R.Singer. Estimation of age from cranial suture closure. A report of its unreliability. J.Foren.Med. (S.Afr).1953; 1:52-59.
32. **32.** A.K. Moondra Age assessment from vault suture closure in elderly persons (an autopsy study in Haroti Region); Desertation for M.D.: University of Rajasthan; 2000.
33. **33.** A.Nandy.Principles of Forensic Medicine .1st Ed.New central book agency (p) ltd, Kolkata; 1995:77-83.
34. **34.** P.C.Vyas.Age estimation by closure of sutures of skull in individuals of 25-45 years of age of Jaipur area. Dessertation for M.D.; University of Rajasthan: 1996.
35. **35.** C.K. Parikh. Parikh's Text Book of Medical Jurisprudence and Toxicology: 5th Ed.Mumbai.Medicolegal centre, Colaba.1990:44-45.

Download the original thesis document (PDF document, 956 KB)