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Sex Determination from Digital Radiographs of Costal Cartilage: A Cross Sectional Study

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Abstract:

The aim of this study was to study the pattern of calcification found in cartilage of costal region with the aid of digital radiographs in male and female. PA chest digital radiographs were taken and with the help of software IMAGEWORK radiological evaluation of calcification pattern were done. With the help of IMAGEWORK we can alter the contrast, magnify the radiograph, can increase or decrease the sharpness and brightness that help in greater visualization and help in better evaluation on type of pattern as compare to conventional mean. Other advantage is it is cost and time efficient. Three main distinct calcification pattern were seen in the present study. In males' peripheral type of calcification was dominant where as in females' central type was more seen. Mixed type of pattern was more common in age group 20- 40. In males at age of 16 calcification was noted whereas in females at age of 18.

Keywords: *Digital Radiographs, Costal Cartilage, Calcification, Sexual Dimorphism.*

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Introduction

In conditions of natural or manmade mass disasters, genocides or aircraft accidents where direct or positive identification of victims is difficult, there is a need for an accurate, timely, simple and inexpensive method of sex determination. For the purpose of identifying victims, one such method that has proved reliable is the use of high-resolution chest radiographs. A radiological examination of costal cartilage calcification using digital radiographs is an easy, fast, and low-cost method of determining sex. It may be a kind of screening test for subjects who need sex identification after puberty.

For the identification of any individual, there are characteristic biological factors. Bone being resistant to putrefaction and damage caused by animals can be used for identification and can help in the estimation of age, gender and race. For human identification by skeletal structure different identity procedures are provided in anthropology. With age, costal cartilages may undergo calcification which occasionally can be useful in establishing sex in forensic anthropology if the pelvic bones and skull are not available **(Scheuer, 2002; Cunningham, 2016; Thompson and Black, 2006).** This might occur for example with recently deceased dismembered remains, even though the definitive ascription of the sex of recent remains usually would be established by DNA analysis. Fischer was among the first to suggest that costal cartilage calcification may show a sex-related pattern **(Fischer, 1995).** This has been confirmed and studied further by several authors **(Middleham, 2014; McCormick *et al.*, 1985).** The recent studies into sex determination based on costal cartilage calcification have visualized it using radiographs of the anterior chest wall.

King (1939) in his study emphasized the importance of using the word "calcification", as well as the distinction between calcified cartilage matrix and bone.

Sex identification is very important compared with age and race identification as it excludes almost half of the population. The most anthropological methods used for sex identification are directly measuring the skeletal remains. The most common problems for obtaining intact bones are trauma, disappearance and decomposition for diverse causes. The human thoracic region is relatively important in biological and forensic anthropological studies as it is active between adolescent growth and adult maturational and degenerative periods **(Torwalt and Hoppa, 2005).** As such, it presents a chance to get information with reference to personal identification during much of an individual's lifetime and should be especially important when handling only partial remains, where sex determination and age estimation may become harder. Most anthropological methods for handling situations of questionable identity are developed to be used on dry bone and, at the very least, require a partially or defleshed body. While all individuals requiring a forensic examination are in some stage of decomposition, within the majority of situations these bodies are relatively intact. In such instances, it's going to be an easy procedure to initiate identification processes using fingerprints, visual confirmation, unique physical characteristics, dental records, or past medical procedures as evidence **(Manigandan, 2015).** However, in certain circumstances, the private parts may be too decomposed to use these techniques, or ante-mortem medical and/or dental records may be incomplete, inaccessible, or difficult to obtain. Thus, any technique that's ready to facilitate a rapid, simple, and cheap determination of sex is extremely important. Of particular relevance to the present study, is the determination of sex in forensic contexts from radiographs of the chest.

Review of Literature

Elkeles (1966) radiographed 2606 patients (1329 male and 1277 female) between the age group of 30-80. Their findings show linear density perichondrium calcification predominantly for the male sample. Whereas in female calcification was shown by bands of dense granules. The percentage level of calcification was higher in females 5% than in males.

Navani *et al.* (1970) evaluated the prevalence of costal calcification in males and females and examined the influences of age and sex on patterns of costal cartilage calcification. Calcification is divided into three main categories- marginal, central and mixed. Frontal chest radiographs of 1000 in-patients, ranging in age from 1o to 95 years, at the Boston City Hospital, were chosen at random and examined by 2 independent observers. Type I calcification appeared alone or in combination with other types in 69.8 per cent of the males as compared with 11.3 per cent of the females. Type III calcification occurred rarely in both males (0.2 per cent) and females (1.3 per cent). The frequency of mixed calcification was about 7 per cent in both males and females. In males, the prevalence of Type I calcification increased from 3.3 per cent in males under 20, to 89.3 per cent in males over 60 years of age.

Rao and Pai (1988) took Material for the study consisting of 1000 chest radiographs of a southern Indian population (512 males & 488 females) ranging from 1-80 years. They divided the peripheral type into two sub-categories. All three patterns were mostly confined to lower ribs from the 5th to 12th rib. Calcification occurred much earlier in females than in males. Calcification in the upper four ribs was found beyond the age of 50.

Inoi (1997) studied 110 Japanese cadavers consisting of 55 males and 55 females. The fourth right costal cartilage was studied radiologically to examine the pattern of sex. Detailed investigation of the internal structure at the distal ends of the ribs and the shape of the costochondral junction revealed better estimates of age compared with the degree of calcification alone, which showed wide individual variation.

Rejtarová, *et al.* (2009) conducted a study aimed to evaluate differences in male and female ageing with respect to costal cartilage. The sample size consists of 1044 chest and abdominal radiographs of the Czech population (537 were male and 507 females). Further 18 chest plates were obtained of cadavers. They classified the patterns of calcification as follows:

Type I – Peripheral pattern
Type IIa – Central lingual pattern, characterized by pyramidal-shaped central tongues of calcification beginning at the fossae (the fossa at the anterior end of a rib at the union with the costal cartilage).
Type IIb – Central globular pattern, consisting of centrally placed, smoothly contoured globules of calcification.
Type IIc – Central lingual and globular pattern.
Type III – Mixed (peripheral and central pattern).
Type IV – Indifferent pattern—incipient calcification without differentiation into a sex-specific pattern.

It was stated that sexual dimorphism within the human thoracic area may include morphological as well as metric alterations in the sternum and 4th rib (**Torwalt, and Hoppa, 2005).** Using a sliding calliper measurement was done to the possible nearest mm value. Logistic regression analysis was done for sex estimation. Sex prediction accuracy was 95.8% and 90.3% in males and females respectively with the 4th rib and sternal region.

Middleham *et al.* (2014) studied a sample of the Scottish population. 41 cadavers (22 male and 19) aged 57-96 years were studied by two different methods. With one method, none of the male samples was sexed correctly. Whereas with another method, 82.4% of the male was correctly sexed but only 41.2% of female. They used a new method based on whether calcified deposits were trabecular bone or sclerotic calcified deposits.

Zhang *et al.* (2017) 154 patients undergo dual-energy tomography for the study of calcification in the Chinese population. Patient age varies from less than 30 to more than 60 in this study. They study four types of calcification patterns central, peripheral, mixed and none. The findings suggest progress in calcification before 40–50 years old and a sharp bone loss after 40–50 years old in females. Calcium concentration of cartilage went on a gradual rise and peaked in their 40–50 years.

Maruyama and Yamamoto (2013) studied and made an easy way of learning the positioning of the patient for the person studying radiography. The tool helps in a greater understanding of anatomy and positioning without radiation hazards.

Holcombe *et al.* (2017) [19] measured volumes and extents of costal cartilage calcification from 205 live subject CT scans. Significant increases in volume calcification – both in a given cartilage segment and in the lengthwise extent of those segments that experience calcification – are seen with age ($p<0.001$). Age and sex described for 35% of all inter-individual people changeability. Precise commendations for introducing person-age via regional calcification to models of the costal cartilage are that (1) calcification volume within a segment should increase at the rate of 0.9 mm per decade, and (2) involve an increasing lengthwise extent of the cartilage segment at a rate of at least 7% per decade.

Agarwal *et al.* (2015) conducted at Ahmedabad compromising 2291 radiographs from ages ranging 1 day to 92 years. No. radiographs showing calcification were higher in this study as compared to other studies which were done earlier because they use computer software applications.

Aim and Objectives

The aim of the present study is to radiologically evaluate the anatomy of normal posteroanterior chest radiographs of adults. To study the pattern of calcification in the chest and evaluate it. To evaluate the prevalence of costal calcification in males and

females. To examine the influences of age and sex on patterns of costal cartilage calcification. To study the type of pattern of costal cartilage in both sexes.

Significance of the Study

This study will provide a fast, simple, and less costly method of sex determination from human chest radiographs when other conventional methods typically used are not effective. The chest radiograph is usually demanded radiograph and the radiation dose to the patient is very minimal. Therefore, the need to use chest radiographs to determine sex is highly required.

Material and Methodology

For this cross-sectional study data of digital radiograph was taken from the government civil hospital Nadaun (Himachal Pradesh). A total of 200 digital radiographs of the chest which were reported normal by the radiologist from the DICOM software were taken. The radiographs were selected after following inclusion and exclusion criteria. The radiographs were divided based on age into four groups: 10-20, 20-40, 40-60, 60 and above. 100 radiographs were of each gender. The calcification pattern was divided into four types. Type 1 is termed as Peripheral (calcification at superior and inferior costal cartilage), Type 2 as Central (centrally placed calcification) and Type 3 as mixed (combination of Peripheral and central) and Type 4 as Indifferent (a calcification pattern which cannot be categorized in any type).

Inclusion and Exclusion Criteria

Inclusion Criteria

Normal posterior-anterior chest X-rays of both sexes above 10 years will be considered for the measurements.

Exclusion Criteria

1. Plain chest posterior-anterior radiograph of the subject under 10 years of age with incomplete ossification.
2. Normal posterior-anterior chests X-ray without any deformity, cardiovascular disease or degeneration will be considered for the estimation.

Sampling Technique

In this study posterior-anterior chest radiographs of 10 – 60 and above years old people that will be reported normal will be randomly selected from Radiology Department. The radiographs will be divided into four age groups of age range: 10 to 20, 20 to 40, 40 to 60, 60 and above.

Equipment

1. Xray plant for taking an x-ray of the subjects.
2. FCR PRIMA CONSOLE and IMAGE WORKS of Fujifilm.

Patient Position and Technique

Posterior-anterior (PA) Erect View or Frontal View: The patient is placed facing the stand with the chin extended and targeted to the middle of the stand with the cassette in. The feet area unit is placed slightly apart so that the patient achieves a stable stance. The median mesial plane is adjusted at a right angle to the middle of the cassette stand. The dorsal facet of each hand is positioned below and behind the hips with the elbows brought forward. as an alternative, the arms encircle to allow the shoulders to rotate forward and downward and area unit accessible in-tuned with the chest stand. This position avoids a superimposition of the scapulae over the respiratory organ fields. The breasts ought to be compressed against the screen to prevent them from obscuring the respiratory organ bases and diaphragm. The horizontal central x-ray is directed initial at right angles to the container at the extent of the fourth dorsal vertebra, then angulate 5°caudally to create the central ray that coincides with the centre. As a result, the field is restricted to the film/detector, while not supererogatory exposure to go and eyes. Image processing: computed radiography requires the cassette to be removed from the X-ray machine and then placed into a reader. Fujifilm FCR PRIMA will be used along with FCR PRIMA CONSOLE to scan an X-ray image. The software IMAGE WORKS will be used for viewing the image on the computer. This software already has the measurement scales in it so we are not going to do any calculations by conventional ruler or compass. One of the major benefits of using IMAGE WORKS is we need not take the hard copy of the radiographs. We can store it in soft copy form thus making this study more cost-effective.

Result

A total of 200 digital radiographs was taken out of which 76 showed calcifications. 41 radiographs of males showed the presence of costal cartilage calcification whereas 35 of females showed calcification (Table No. 1).

Table No. 1: Number of Radiographs showing Calcification

SEX	PRESENT	ABSENT	TOTAL
MALE	41	59	100
FEMALE	35	65	100
TOTAL	76	124	200

2 radiographs out of 64 radiographs in the age group of 10-20 showed the calcification, 15 radiographs in the age range 20-40 years showed the presence of calcification (Table No. 2).

Table 2: Calcification of Costal Cartilage in different Age Groups

AGE GROUP	PRESENT	ABSENT	TOTAL
10-20	2	62	64
20-40	15	34	49
40-60	28	20	48
60 and above	31	8	39
TOTAL	76	124	200

Percentage of costal cartilage calcification in the age group 60 and above showed a higher percentage (41%) of calcification (Figure No. 1) as compared to other age group.

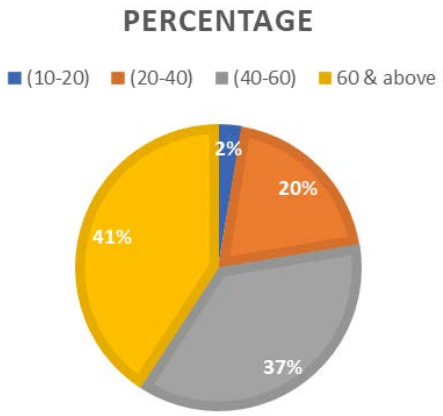

Figure No. 1: Distribution of Costal Cartilage in different Age Groups.

The number of radiographs was 64 in the age group of 10-20 (Table No. 2), 49 radiographs in 20-40, 48 in the age group 40-60 and 39 in the age group 60 and above out of 200 radiographs. In males 21 radiographs out of 34 radiographs showed calcification in age group60 and above, 13/25 in the age group 40-60, 5/22 in the age group 20-40 and 1/19 in the age group 10-20 (Table No. 3). In females 18/24 in the age group 60 and above, 12/27 in the age group 40-60, 4/28 in the age group 20-40 and 1/21 in the age group 10-20 (Table No. 3).

Table No. 3: Costal Cartilage Calcification in Males and Females in the different Age Groups

AGE GROUP	PRESENT in males	ABSENT in males	TOTAL (Males)	PRESENT in females	ABSENT in females	TOTAL (Females)
10-20	1	18	19	1	20	21
20-40	5	17	22	4	24	28
40-60	13	12	25	12	15	27
60 & above	21	13	34	18	6	24
TOTAL	41	59	100	35	65	100

Table No. 4 showed the distribution of the different patterns of calcification in males and females Type 1 calcification was found in 33 males (Figure No. 2) and 2 in females. Type 2 calcification was seen in 2 in males and 29 in females (Figure No. 3). Type 3 calcification pattern was seen in 6 males and 3 in females (Table No. 4). 1 female digital radiograph showed an indifferent pattern.

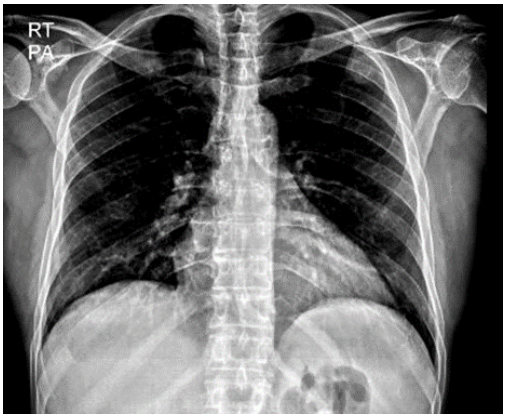

Figure No. 2: Peripheral Calcification in the Male Radiograph

Figure No. 3: Central type Calcification in the Female Radiograph

Table No. 4: Types of Costal Cartilage Pattern

SEX	TYPE 1	TYPE 2	TYPE 3	TYPE 4
Male	33	2	6	00
Female	2	29	3	01
Total	36	25	15	01

Conclusion

The pattern of calcification was peripheral type in males and central type in females in the present study. 80% of the male calcification was (peripheral) type 1. 83% in females was (central) type 2. The earliest radiograph showing calcification was seen in 16 years of males and 18 years in females. The present study showed the presence of sexual dimorphism in the pattern of costal cartilage calcification. The percentage of calcification was seen increasing with age. The incidence of costal calcification was observed low in the age group of 10-20 and 20-40. The presence of calcification was easy to visualize on a digital radiograph as compared to conventional radiographs as we can magnify and increase or decrease contrast as per requirement. Costal cartilage calcification can be used for the identification of sex when the thoracic cage is only present. Sex determination using a radiograph is an easy and fast method of identification. The present study is a non-destructive way of identification.

References:

Agarwal, Harish Kumar S., et al. "Application of Software Tool for Sex Determination from Calcification Pattern of Rib Cartilage in Digital Radiographs." *Journal of Indian Academy of Forensic Medicine*, vol. 37, no. 3, 2015, p. 263. *Crossref*, doi:10.5958/0974-0848.2015.00066.4.

Cunningham, Craig, et al. *Developmental Juvenile Osteology*. 2nd ed., Academic Press, 2016.

Elkeles, Arthur. "Sex Differences in the Calcification of the Costal Cartilages." *Journal of the American Geriatrics Society*, vol. 14, no. 5, 1966, pp. 456–62. *Crossref*, doi:10.1111/j.1532-5415.1966.tb03071.x.

Fischer, E. "Verkalkungsformen Der Rippenknorpel." *RöFo - Fortschritte Auf Dem Gebiet Der Röntgenstrahlen Und Der Bildgebenden Verfahren*, vol. 82, no. 04, 1955, pp. 474–81. *Crossref*, https://doi.org/10.1055/s-0029-1212570.

Holcombe, S. A., et al. "Calcification of Costal Cartilage in the Adult Rib Cage." *International Research Council on Biomechanics of Injury (IRCOBI)*, 2017, pp. 737–44. *Proceedings of the 2017 International IRCOBI Conference on the Biomechanics of Injury*.

Inoi, T. "Estimation of sex and age by calcification pattern of costal cartilage in Japanese." *Nihon hoigaku zasshi = The Japanese journal of legal medicine* vol. 51, no. 2, 1997, pp. 89-94.

King, John B. "Calcification of the Costal Cartilages." *The British Journal of Radiology*, vol. 12, no. 133, 1939, pp. 2–12. *Crossref*, doi:10.1259/0007-1285-12-133-2.

Manigandan, T., et al. "Forensic Radiology in Dentistry." *Journal of Pharmacy and Bioallied Sciences*, vol. 7, no. 5, 2015, p. 262. *Crossref*, doi:10.4103/0975-7406.155944.

Maruyama, Toshinori, and Hideki Yamamoto. "Positioning Training Tool for Radiography." *Positioning*, vol. 04, no. 04, 2013, pp. 289–300. *Crossref*, doi:10.4236/pos.2013.44029.

McCormick, William F., et al. "Sex Determination from Chest Plate Roentgenograms." *American Journal of Physical Anthropology*, vol. 68, no. 2, 1985, pp. 173–95. *Crossref*, doi:10.1002/ajpa.1330680205.

Middleham, Helen P., et al. "Sex Determination from Calcification of Costal Cartilages in a Scottish Sample." *Clinical Anatomy*, vol. 28, no. 7, 2014, pp. 888–95. *Crossref*, doi:10.1002/ca.22491.

Navani, Shiv, et al. "Determination of Sex by Costal Cartilage Calcification." *American Journal of Roentgenology*, vol. 108, no. 4, 1970, pp. 771–74. *Crossref*, doi:10.2214/ajr.108.4.771.

Rao, Nageshkumar G., and Lakshman M. Pai. "Costal Cartilage Calcification Pattern — A Clue for Establishing Sex Identity." *Forensic Science International*, vol. 38, no. 3–4, 1988, pp. 193–202. *Crossref*, doi:10.1016/0379-0738(88)90166-1.

Rejtarová, Olga, et al. "Sexual Dimorphism of Ossified Costal Cartilage. Radiograph Scan Study on Caucasian Men and Women (Czech Population)." *Forensic Science International*, vol. 191, no. 1–3, 2009, p. 110.e1-110.e5. *Crossref*, doi:10.1016/j.forsciint.2009.06.009.

References:

Scheuer, Louise. “Application of Osteology to Forensic Medicine.” *Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists*, vol. 15, no. 4, 2002, pp. 297–312. *Crossref*, doi:10.1002/ca.10028.

Thompson, Tim, and Sue Black. *Forensic Human Identification: An Introduction*. 1st ed., CRC Press, 2006.

Torwalt, Carla R. M. M., and Robert D. Hoppa. “A Test of Sex Determination from Measurements of Chest Radiographs.” *Journal of Forensic Sciences*, vol. 50, no. 4, 2005, pp. 1–6. *Crossref*, doi:10.1520/jfs2004425.

Zhang, Shanyong, et al. “Characteristics of Chinese Costal Cartilage and Costa Calcification Using Dual-Energy Computed Tomography Imaging.” *Scientific Reports*, vol. 7, no. 1, 2017. *Crossref*, doi:10.1038/s41598-017-02859-x.