

Characteristic of costal cartilages calcification in relation to sex and age: A forensic review in Aden population

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Abstract

In recent years, there has been renewed interest in forensic sciences about forensic age and sex estimation in living subjects by means of radiology. Costal cartilage bridges, the sternum and the ribs play a key role in the biomechanics of the chest, and is known to be calcified in local regions with age. This study aims at finding out the patterns of costal cartilage calcification in relation to sex and age, and was conducted on digital thorax X-rays to test the usefulness of some radiological changes in the costal cartilage.

A descriptive cross sectional study of 1371 radiographs of chest plates were collected from a Diagnostic Medical Center (DMC) in Aden city / Yemen, during the period January 2017 to December 2018, all data were analyzed for their calcification patterns according to the methods of McCormick et al. The incidence of calcification increased with the advancement of age and the earliest appearance of calcification in costal cartilage was seen at 18-19 years in both sexes but more significantly in females. The tendency of central calcification of cartilage was displayed in females, while the peripheral calcification preferred in males, and the mixed calcification seen in both sexes but more in males. It is safe to conclude that different patterns of calcification at rib cartilage observed in digital radiographs are sex specific, that is to say male subjects predominantly show peripheral pattern and female subjects predominantly show central pattern. Calcification of costal cartilage starts at the age of 18-19 years in both sexes and increases with age.

Key words: Costal cartilage, Calcification, Sex determination, age estimation, Ribs.

Introduction

Forensic radiology is a sub-specialization of forensic medicine defined as the discipline that "utilizes the interpretation of medical radiological examinations to answer legal questions", the importance of radiographic methods has been long now acknowledged in medico-legal practice as in the biological profiling of the deceased people as well as in age and sex estimation methods^[2]. The age and sex determination through skeleton calcification is of very much interest in the field of forensic medicine^[7]. In the adult skeleton, sex determination is usually the first step of the identification process as subsequent methods for age and stature estimation and are sex dependent. It has long been established that there is a distinct difference in sex patterns of costal cartilages calcification that can provide a useful method of sexing, Previous studies have used simple X-ray to utility of bones for age and sex assessment, the earlier studies identified sexual dimorphism in the ribs by focusing on the patterns of costal cartilage ossification as revealed by (McCormick, Stewart, Elkeles, Sanders, Navni, Rao and Pai)^[13,3].

Anatomically, the skeleton of the thoracic wall consists of twelve thoracic vertebrae with their intervertebral discs, the twelve pairs of ribs with their costal cartilages and the sternum. There are twelve pairs of ribs that articulate with the vertebral column posteriorly and costal cartilages anteriorly. The costal cartilages are persistent, unossified anterior parts of the cartilaginous models in which the ribs develop, they are flat bars of hyaline cartilages that extend from the anterior ends of the ribs and contribute greatly to thoracic mobility and elasticity, whereas the costal cartilages of the upper seven pairs of ribs are connected directly to the sternum and they are classified as true or vertebral ribs, the remaining five pairs of ribs are classified as false ribs^[9].

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Calcification is the process in which the mineral calcium builds up in soft tissue, causing it to harden and the ossification is the process of bone formation in which cartilages are turned into bone. The endochondral ossification appears in the first decade and they correspond to ossification detected by X-ray in the second decade. The location of sex ossification is determined by the penetration of cartilage canals into the rib. Endochondral intramembranous ossification appears after the third decade. This type corresponds to the central globular ossification detected by X-ray, and it is not sexually dimorphic. It can serve for accurate estimation of age [10].

Previous studies have attempted to correlate the costal cartilage calcification with many pathological states, e.g. arteriosclerosis, nutritional state, metabolic or endocrine changes. The costal cartilage calcification progresses with the age and it shows differences in sexual preponderance. Studies have been done on these parameters. But, few studies have been done on encompassing age, sex and effect of calcification on chest expansion. [5]. Establishing the identity of person is one of the significant aspects of forensic investigation, so the age and sex are important points usually noted for the purpose of identification, the progressive calcification of costal cartilages exhibits the age and helps to elucidate the sex distinctive pattern, this process proceeded from the costal toward the sternum end of the cartilage in an anteromedial direction, the first rib cartilages were not considered because there are no sex differences [8], it prone to calcification after adolescence that means it occurs with advancing age, which is observed more frequently in the first costal cartilage [9].

The differences between males and females in costal cartilage calcification were first described by Fischer in 1955; later, other authors described the differences in their studies [8].The use of costal cartilage ossification patterns for age determination has been undertaken in the past to observe patterns of calcification at rib cartilage, which are reported to be useful, convenient and sex specific; most of them were performed in western countries [9,12].

The importance of radiological methods has been long now acknowledged in medico-legal practice as the biological profiling of deceased people as well as in the age and sex estimation method. Therefore, this study aims at finding out the patterns of costal cartilage calcification in relation to sex and age.

Methods

A descriptive cross sectional study for digital chest X-rays of 1371 subjects (779 males and 592 females) of the age ranging from 16 to 67 years, who came to the Diagnostic Medical Center (DMC) in Aden city / Yemen, for medical purposes in the period January 2017 to December 2018, all of them have birth certificates indicating their real ages, without any pathological conditions affecting the bony thorax.

An anteroposterior (AP) view for chest radiograph was taken for each patient using the x-rays machine. The chest radiographs were examined to determine the site and the extent of calcific changes for the present patterns of the costal cartilage calcification. The grade of the costal cartilage calcification was calculated by measuring breadth between its costal attachment and sternum ends of the ribs. Age group, calcification of costal cartilage was graded from 0 to 7 based on McCormick, Stewart and Barchilor and the patterns of costal cartilage calcification were determined in both sexes as per Verma's methodology, as illustrated in Table (A) [9].

Statistical analysis

Data were processed by using Statistical Package for Social Sciences (SPSS) for Windows version 20.

Ethical consideration

Ethical approval has been taken from the Committee of Ethics in the Faculty of Medicine and Health Sciences, University of Aden.

Table A: Verma's methodology Grade of Calcification in Costal Cartilage

Grade	Appearance of calcification in costal cartilage
Grade 0	No calcification.
Grade 1	Trace of calcification.
Grade 2	Calcification along the single margin of the costal cartilage.
Grade 3	Calcification along both margin of the costal cartilage.
Grade 4	Prominent central or bifid calcification.
Grade 5	Mixed – marginal and central less than 50% of calcification.
Grade 6	Mixed 50 - 74% of calcification.
Grade 7	Calcification around 75 % and above.

Results

In this study, 1371 digital X-rays for chest were evaluated of known age and sex, 779 (56.8%) were males and 592 (43.2%) were females. The mean age of males was 27.4 ± 1.5 years, while the mean age of females was 29.3 ± 1.85 years, all of them with an age ranging from 16 to 67 years old, as shown in Table (1).

In Table 2, there is an increase in grading of costal cartilage calcification in all ribs with an increase in age, the calcification of costal cartilage was rare before the age of ≤ 20 years and was observed more frequently and more extensively with aging. The earliest age at which costal cartilage calcification was observed in adult life was at the age of 18-19 years in both sexes, but more significantly in females and has progressed at individual rates proceeding from the costal towards the sternal end of the cartilage. Among males ≤ 20 years group, the maximum distribution of calcification is in grade 1, in age group 21-30, 31-40 and 41-50 years the distribution is more in grade 1 and 2 respectively, while in ≥ 51 years groups, it's found more in grade 6 and 7, while the costal cartilage calcification among females ≤ 20 years age group the maximum distribution is in grade 1, in 21-30 years age groups 1 and 2, and in 31-40 years age group, the distribution of calcification found more in grade 3, while the distribution of calcification in age group 41-50 years seen more in grade 1,2 and 3, but in age group ≥ 51 years was found more in grade 6 and 7. The costal cartilage calcification among females is more when compared to males in grade 1 at the age ≤ 20 years, while in males a higher percentage of calcification is observed at grade 1 and 7 at age ≥ 20 year. Moreover, there was a statistically significant degree of association between sex and pattern of calcification ($\chi^2=157.7$, $DF=3$, $P= 0.000004$), the mineralization changes first detected in the sixth, seventh and eighth costal cartilages adjacent to the sternal borders, namely, grade 1,2,3 (Peripheral calcification - Type – I) as shown in (Fig. 1) which is characterized by subperichondral deposits which contours the upper and lower margin of cartilage and which is shown more in both sexes, but is significantly more in males. On the other hand, grade 4,5 (Central calcification – type - II) as shown in (Fig. 2) which is characterized by the pyramidal (lingual) shape of calcification with a peak towards the sternum, this occurs only in females. The grade 6 and 7 (Mixed calcification - Type - III) as shown in (Fig. 3) which is characterized by both peripheral and central calcification and which occurs in both sexes, but more significantly in males. Finally, the absence of calcification is never true after the age of 40 years.

Table 1: Distribution of age and sex in the study sample (n=1371)

Age group / years	Sex		Total
	Male	Female	
≤ 20	167 (58.2)	120 (41.8)	287
21-30	250 (54.5)	209 (45.5)	459
31-40	164 (53.2)	144 (46.8)	308
41-50	124 (59.6)	84 (40.4)	208
≥ 51	74 (67.9)	35 (32.1)	109
Total	779 (56.8)	592 (43.2)	1371

Table 2: Distribution Patterns of costal cartilage calcification according to age and sex

Age group/ years	sex	Pattern of costal cartilage calcification								Total
		Absent	Peripheral			Central		Mixed		
		Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	
≤ 20	M	136	31	0	0	0	0	0	0	167
	F	78	39	3	0	0	0	0	0	120
21-30	M	29	113	78	22	0	0	8	0	250
	F	15	89	65	23	4	4	4	5	209
31-40	M	13	58	40	10	0	0	23	20	164
	F	6	22	25	43	5	13	13	17	144
41-50	M	3	40	36	15	0	0	17	13	124
	F	2	14	14	18	0	7	20	9	84
≥ 51	M	2	5	9	5	0	0	25	28	74
	F	3	2	0	0	0	0	15	15	35
Total	M	156	247	163	159	0	0	73	113	779
	F	104	166	107	84	9	24	52	46	592



Fig. 1: Peripheral Pattern of Calcification (Type I) male aged 48 yrs



Fig. 2: Central Pattern of Calcification (Type II) female aged 52 yrs



Fig. 3: Mixed Pattern of Calcification (Type III) male aged 59 yrs

Discussion

The correct diagnosis of sex from unidentified human skeletal remains of fundamental importance in forensic medicine, the present study was undermined to determine the presence of costal cartilage calcification and the influence of age and sex on patterns of costal cartilage calcification.

In the present study, several findings have emerged from these data, the calcification of costal cartilage was rare before the age of ≤ 20 years and the absence of calcification is never true after the age of 40 years, which is more frequently with advancing age mainly between 18-19 years in both sexes, but more significantly in females, which is the earliest age at which costal cartilage calcification was observed. Most studies reported the early appearance of calcification such as Pushpa et al. (2013), who observed earlier the occurrence of calcification at 15 years in both sexes^[4], another study by McCormick et al (1988) found that mineralization of the costal cartilage initially appears at 15 years in female and shows that marked calcification appears after 50 years of age^[11]. A similar context by Grainger et al. reported that the earliest age of calcification appears in the early twenties^[6], but Khatri reported that appear at the age 15 years in males and 17 years in females^[4].

There is an increase in the grading of calcification in all ribs with the increase in age, the calcification of costal cartilage is rare before the age of ≤ 20 years, this agrees with Pushpa et al., Charles et al. and other oldest studies [9].

In this study, it has been found that grade 1 calcification is more common frequent in females than males; while in males shift of higher percentage of calcification was observed at grade 2 to 7, this is in agreement with the finding of Sunwoo et al. [12,9] and disagrees with Koushik et al. of which calcification of costal cartilage is more in the males than females in all age groups [5].

Moreover, another interesting finding was a statistically significant degree of association between gender and pattern of calcification; the peripheral type of calcification of costal cartilage was seen more in both sexes, but more significantly in males, while the central calcification occurs only in females, these findings are similar to Olga, Sunwoo et al., Bozzato, and Zhang et al. [8,12,1,14]. This observation provides an evident that a definite sexual dimorphism is present in the calcification pattern of costal cartilages and this knowledge can be utilized in medico-legal cases to forensic expert for establishing sex.

Conclusion

The present study shows that the calcification of costal cartilage could be considered as an effective method for the identification of sex and age. The calcification of costal cartilage is rare before age ≤ 20 years. There is a statistically significant degree of association between gender and pattern of calcification, the peripheral calcification of costal cartilage is seen in both sexes, but more in males; while the central calcification occurs only in females.

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مميزات تكلسات غضاريف الاضلاع وعلاقتها بالجنس والعمر: استعراض طبي شرعي

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الملخص

حدثت في السنوات الاخيرة تطورات جديدة في العلوم العدلية فيما يخص بتقدير الاعمار وتحديد الجنس عند الاحياء بالطرق الشعاعية نظرا للدور التي تلعبه جسور غضاريف الاضلاع في حيوية ميكانيكية لحركة القفص الصدري حيث من المعلوم ان غضاريف الاضلاع تتكلس موضعيا مع تقدم العمر. تهدف هذه الدراسة الى ايجاد العلاقة بين انماط تكلس غضاريف الاضلاع و الجنس والعمر. تم فحص 1360 صور شعاعية رقمية للصدر وامكانية الاستفادة من التغيرات الشعاعية الملاحظة في غضاريف الاضلاع، واجري بعدها تحليلا احصائيا لأنماط تكلسات غضاريف الاضلاع طبقا لطريقة (ماك كورمك) وزملاءه. وجد ان التكلسات الحديثة تزداد مع تقدم العمر وكان اول ظهور لتلك التكلسات ضمن الفئة العمرية 18-19 سنة عند كلا الجنسين لكنها كانت اكثر أهمية احصائية عند الاناث، بينما لوحظ استعداد الاناث للتكلسات المركزية في غضاريف الاضلاع اما الذكور اكثر استعدادا من الاناث في مدى التكلسات المحيطية بينما النوع المشترك من التكلسات شوهدت عند كلا الجنسين ولكنها كانت اكثر نسبة بين الذكور.

خلصت هذه الدراسة الى ان الانماط المختلفة من تكلسات غضاريف الاضلاع المشاهدة بالصور الشعاعية الرقمية محددة لنوع الجنس البشري. وظهر النمط المحيطي لتلك التكلسات عند الذكور بشكل سائد بينما ظهر النمط المركزي عند الاناث الغالب. كما اظهرت الدراسة ان بداية ظهور التكلسات في غضاريف الاضلاع كان عند الفئة العمرية 18 - 19 سنة في كلا الجنسين مع ازديادها بتقدم العمر.

الكلمات المفتاحية: غضاريف الاضلاع، التكلسات، تحديد الجنس، تقدير العمر، الاضلاع.