ACCURACY OF PATIENTS AGE ASSESSMENT FROM FRONTAL CHEST RADIOGRAPHS

M. Hameed[1*], S. Mahar[2], B. Das[3], A. R. Khumaini[4], A. Ullah[5] and M. Jamil[6]

[1]Head of Radiology Department, National Institute of Child Health Karachi/JSMU
[2]Consultant Radiologist. National institute of Rehabilitation medicine (NIRM) hospital Islamabad
[3]MBBS, FCPS (Radiology), Assistant Professor and Head Radiology Department CMCH SMBBMU LARKANA
[4]MBBS. FCPS, Consultant Radiologist, Head of Radiology Department, CMH Okara
[5]Assistant Professor, Department of Radiology, Mufti Mehmood Teaching Hospital, Dera Ismail Khan, KP, Pakistan
[6]Arid Zone Research Center, Dera Ismail Khan, Pakistan
*Corresponding author: Marya Hameed, E-mail: Drmash84@gamil.com

ABSTRACT: Background: Chest radiograph interpretation can be aided by knowing the patient's age. Patients' age is often assessed by radiologists from costal cartilage calcification assessment of chest radiographs with anteroposterior views. **Objectives:** Therefore, we performed this research to determine the precision of these radiologists in age estimation from CXRs. **Methods:** Ten radiology experts were selected to evaluate 3500 chest digital radiography with posterior-anterior images, in National Institute of Child Health Karachi/JSMU from January 2022 to 2023. The most important inclusion criteria were selecting normal or nearly normal radiographs in the study. Radiologists were blind to patients actual age and were requested to determine patient's age to closest decade from CXR. The respondents entered their responses in separate Excel spreadsheets. **Results:** A sum of 3,500 CXRs was interpreted by radiologists, out of which 32.14% CXRs were correctly interpreted determining age at SD $\pm$ 3 years, whereas 2375 CXRs were either overrated or underestimated ($p<0.05$) and misinterpreted the age of patients (2375/3500; 67.85%). **Conclusion:** Overall age assessment from a frontal CXR was only 32.14% in our study; considerable disparities were identified in age estimation using CXRs. Yet, it would be fascinating to expand this academic endeavor through artificial intelligence tools and possibly improving the precision of patient age prediction from CXR. This approach for determining the age will be useful for screening tests in the prospect.

Keywords: Chest X-rays; Costal cartilage; Geriatric patients; Radiology; Skeletal interpretation.

(Received 28.10.2022 Accepted 27.02.2023)

INTRODUCTION

Aging refers to a collection of interrelated decreases in function associated through increasing chronological age. Alleged age or individual's assessed age is a reliable biomarker of aging. Clinicians compare perceived and chronological age apparently. Earlier clinical research demonstrated that older perceived age patients, *i.e.*, those who appear older than their chronological age, bear advanced carotid atherosclerosis, decreased bone mineral density and an increased risk of mortality (Leki *et al*., 2022; Kido *et al*., 2012; Nielsen *et al*., 2015).

Using medical pictures to estimate one's age is not new, for instance since 1937, hand X-rays have been used to determine one's bone age in diagnosing endocrine growth abnormalities of pediatric population. Bone density scored drop with aging (DEXA scans), while calcium scores for coronary arteries increase with aging (CT scans) and are further related instances. Occasionally, radiologists may also reveal that CT scan of patient's brain reveals "chronic ischemia microvascular alterations, atrophy *etc*., to patient's age." Numerous medical imaging methods frequently provide visual information regarding the internal anatomical structures of the person. This found an association between imaging visual features and one's age formulates the topic fascinating for researchers (karargyris *et al*., 2019).

Deep learning tools including convolutional neural network (CNN) regressions, are highly accurate and potentially better fitted for assesing age of unidentified patients. However, CNN models are not readily accessible nor are first-line approach in current health departments (Sabottket *et al*., 2020). But CXR is the most widespread investigative imaging modality being economical, widely existing and speed of performance. CXR plays a vital role in hospital and community ailments investigation and surveillance (Cardinale *et al*., 2012). The ability to estimate patient age from chest radiographs can have substantial ramifications in everyday practice. An age estimate derived from a chest x-ray can abet in establishment of accurate diagnoses, prognoses, and treatments. The osteogenic characteristics of digital X-rays can be

employed as age predictors in Physical Anthropology domain (Chibane *et al*., 2022).

Thus, the study was purposed to evaluate the ability of contemporary radiologists and radiology residents in predicting patient age from normal CXR taken using modern technologies.

MATERIAL AND METHODS

Ten radiology experts were selected to evaluate 3500 CXR with anterioposterior images, in National Institute of Child Health Karachi/JSMU. The photos were taken from a radiologist's randomly assigned daily reading catalog at diagnostic centers for adults from January 2022 to January 2023. The most important criterion for selecting radiographs selection of only normal or nearly normal CXR for this research. It was attempted to acquire a plenty number of radiographs of women and men, as well as a comparable distribution among age groups. According to demographic information entered in the patient's electronic medical chart, the true age of the patient was determined. Each chest radiograph was assigned a sequential number from 1 to 3500 and the images were put in the record as well as recording the summary of the patient's demographic information. All radiologists were blinded to the demographics of patients and were requested to estimate patient age to the closest decade for each chest radiograph. The respondents entered their responses in separate Excel spreadsheets. Age and gender were determined based on the costal cartilage. For age estimation, the costal cartilage of 1st right rib and sex was determined via consider the other ribs from CXR (Figure 1). Several investigations have demonstrated that sex is unrelated to initial costal cartilage calcification, although sexual dimorphism was observed in the lower rib cartilage. The study used two principles *i.e.* the costal cartilage calcification pattern for gender estimation and calcification degree was used to determine the age (Patyal and Bhatia, 2022).

In current research, all succeeding CXR were reported by radiologists from inpatient and outpatient situations. In actual clinical practice, the CXR cases were reported with the assistance of an AI tool utilizing high-resolution diagnostic radiology monitors within radiologists' typical reporting context. CXR cases were reported both on-site and remotely in accordance with the standard workflow of a major radiology network spanning a vast geographical area with numerous regional and distant clinics. Radiographs of patients below 10 years were eliminated.

The study was granted ethical approval from the institutional review committee and all responses were compiled using Microsoft Excel which was also used for data extraction and analysis. This was accomplished by securing the data in multidimensional arrays through conditional loops, exclusively for examination of approximation disparities explicit to each age group. Simple statistical computations were performed to assess accuracy based on person's readers and patients' gender. Age estimations are measured using percentages of right predictions and weighted average deviations in decades from the correct age group. When calculating the accuracy disparity among the patients, confidence intervals were computed through t-test on small specimens. The accuracy of the radiologists was a qualitative measure of an estimate's proximity to extent of correct age group.

RESULTS

The study was conducted in National Institute of Child Health Karachi/JSMU 2022 to January 2023, comprising 10 radiology experts to evaluate 3500 chest digital radiography with posterior-anterior images. The demographics of the patients were recorded blindly by the radiologists and were categorized into age groups based on age decade groups and sex groups. 2191 of the patients were males (62.60%) and 1309 CXRs of females (37.40%) were examined. A significantly high number of CXRs were scrutinized for the age group 31-40 years (927/3500) and the least number of CXRs were found for the age group >70 years (71/3500) (Table 1). Figure 2 depicted the demographics and expertise of radiologists tasked with determining the patient's age. The radiologists were classified into four categories depending on their professional expertise. Category 1 featured one male and one female radiologist with 5 years of experience, category 2 contained 03 male and 01 female radiologist with 5-10 years of experience, two men and one female radiologist had 15 years of experience, and one male radiologist had >15 years of skills (Figure 2).

Radiology professionals examined 3,500 CXRs to estimate the age of patients based on their costal cartilage analysis. Just 1125 CXRs were correctly interpreted at a standard deviation of $\pm$3 years, whereas 2375 CXRs were either overrated or underestimated (Figure 3). The expertise of each radiologist deputed in this research was studied individually and it revealed the highest accuracy rate was exhibited by the 10th radiologist (55.14%), followed by the 3rd radiologist (43.65%), 6th radiologist (35.36%), 5th (31.46%), 1st (30.83%), 9th (28.78%), 2nd (25.65%), 7th (24.45%), 8th (24.40%), and least accuracy by 4th 16.27% (49/301) (Table 2). Discrepancies found in the age estimation in CXRs interpreted by the radiologists were statistically studied and a significant proportion of them ($p<0.05$) misinterpreted the age of patients (2375/3500; 67.85%), out of which 43.77% CXRs were overestimated from the patient's actual age and 24.08% were under-rated from their chronological age values (Table 3).

Figure 1: Chest X-ray for age determination of the patients

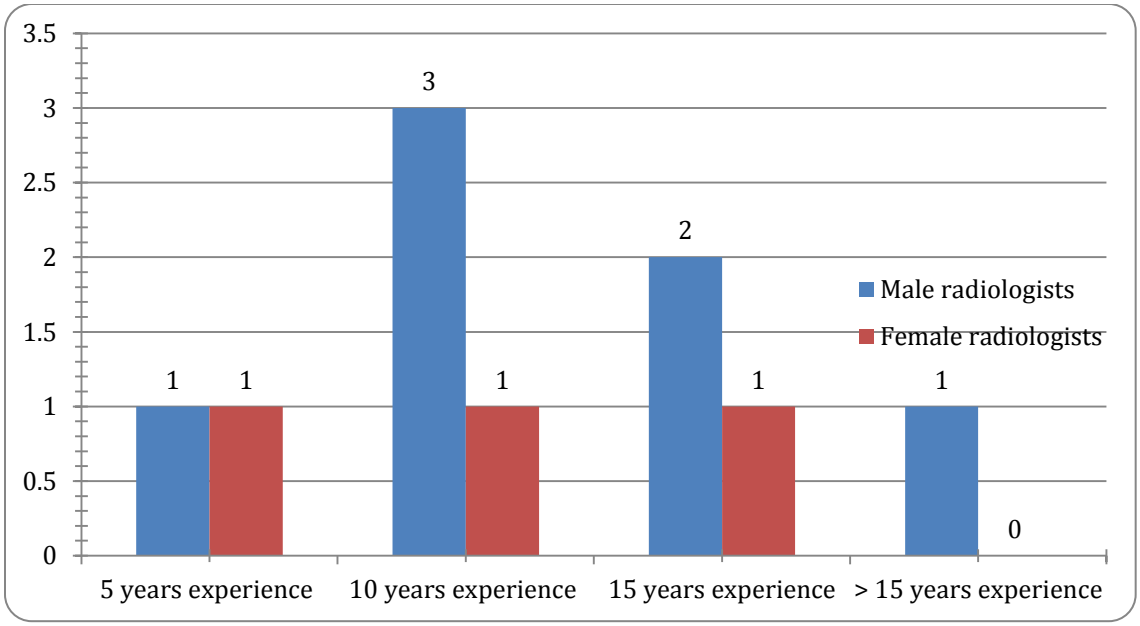

Figure 2: Demographics and expertise of radiologists in age determination.

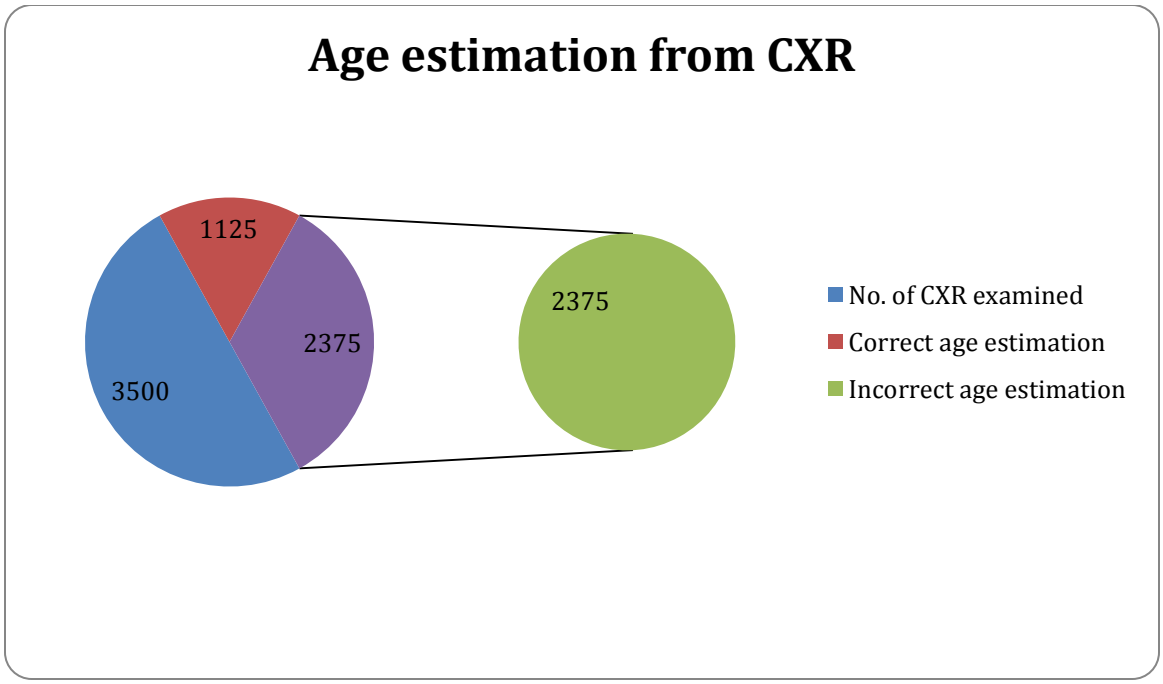

Figure 3: Accuracy of age estimation from the examined radiographs by radiology experts

Table 1: Demographics of the patients for whom CXRs were examined.

S. No	Study variable	No. of patients (n)	Frequency (%)
1	Age (years)		
	10-20	369	10.54
	21-30	761	21.74
	31-40	927	26.48
	41-50	892	25.48
	51-60	302	8.62
	61-70	178	5.08
	>70	71	2.02
2	Sex		
	Male	2191	62.60
	Female	1309	37.40

Table 2: Accuracy of radiologists in age estimation from CXR of patients

S. No	Radiologist	No. of X-rays examined	Accurate age estimation (SD±3 years) (n)	Percentage of accuracy (%)
1	Radiologist 1	441	136	30.83
2	Radiologist 2	382	98	25.65
3	Radiologist 3	378	165	43.65
4	Radiologist 4	301	49	16.27
5	Radiologist 5	356	112	31.46
6	Radiologist 6	574	203	35.36
7	Radiologist 7	319	78	24.45
8	Radiologist 8	250	61	24.40
9	Radiologist 9	198	57	28.78
10	Radiologist 10	301	166	55.14
	Cumulative	3500	1125	32.05

Table 3: Discrepancies found in the age estimation by CXRs by the radiologists.

S. No	Total CXRs examined	Correct age estimates (n)	Overestimated	Underestimated	p-value	Level of significance (p<0.05)
1	3500	1125	1532	843	0.00001	Significant

DISCUSSION

Chest radiograph interpretation can be aided by knowing the patient's age. It can assist in avoiding the diagnostic error of characterizing symptoms that are considered normal in the elderly as substantial diseases or underselling those that are normal in the elderly age but aberrant in the young. The estimated patients' age is usually determined by the radiology experts from the costal cartilage examination of chest radiographs with anteroposterior views. Therefore, we performed this research to determine the precision of these radiologists in age estimation from CXRs. Our findings revealed that a sum of 3,500 CXRs was interpreted by radiology experts in the study area, out of which 1125 CXRs were correctly interpreted (accuracy 32.14%) for age estimation at SD $\pm$ 3years, whereas 2375 CXRs were either overrated or underestimated ($p<0.05$) and misinterpreted the age of patients (2375/3500; 67.85%). A similar nature study was conducted in Canada in 2022, reporting that staff radiologists were more accurate in age estimations than postgraduate residents. But similar to our findings, patient age was most frequently misinterpreted. Patients younger than 20 years old and older than 90 years old had the least accurate estimates. Those between 50 and 70 years old exhibited the highest accuracy. There was no significant difference between the radiographs of women and men for the accuracy of age estimation. The investigation revealed the mean frequency of accuracy (469/1030 CXRs) at age estimation for only 22% (Chibane *et al*., 2022). Similar interpretations were seen in a study reporting the age determination by plain CXRs (Gross *et al*., 1985). Contrary to our findings, a study reported an accuracy of 94% in age estimation from CXRs (Karargyris *et al*., 2019). Such high precision by manual interpretation is weird and unjustifiable and was not agreed upon.

Another study revealed calcification of 66% of the costal cartilage concerning aging, as measured by CXR during age estimate. In lower CC, the percentage of calcification increases with age, from 0% in the 0–20 age group to 100% in the 61–70 age group. In the study cited above, peripheral calcification was observed in 141 males and 1 female, but central calcification was evident in 132 females and absent in males [8]. A study correlated CXR age estimation with cardiovascular prognosis and found a strong association with chronological age on hold-out test data and independent test data. Higher X-ray age was associated with worse clinical outcomes for heart failure. In addition, increased X-ray age was associated with a worse prognosis in 3,586 patients with cardiovascular illness admitted to the intensive care unit. It was thus implied that X-ray age was a valuable tool for cardiovascular anomalies to assist doctors in predicting, preventing and treating cardiovascular illnesses [1]. Similar nature studies concluding the age estimated by CXR with organs' physiological status were reported by many researchers (Esteva *et al.,* 2017; Rajpurkar *et al.,* 2017; Ribeiro *et al.,* 2020; Coudray *et al.* 2018; Stern *et al.* 2019). It was also reported that the strong impact of CXR viewer on radiologist reporting and recommendations was, however, at the expense of false positives; in 13% of cases, the radiologist rejected several model findings (Jang *et al*., 2020; Hurt *et al*., 2020). Comparing this false positive rate to the false positive rates per case published in previous research exploring CXR models, ranged from 14-88%, and revealed that the chances of discrepancies were significantly higher (Dellios etal., 2017; Sim *et al*., 2019; Collado-Mesa *et al*., 2018; Copley et a., 2009).

Conclusion: Although the overall average rate of appropriate age assessment from a normal front chest radiograph was only 32.14 percent in our study, considerable disparities were identified in age estimation using CXRs. Yet, it would be fascinating to extend this academic endeavor by comparing our findings with artificial intelligence technologies and possibly improving the accuracy of patient age prediction from chest radiography. This approach for determining the age will be useful for screening tests and in circumstances when the thoracic region of the body is discovered, such as in the case of dismembered bodies, skeletal remains, and unidentified bodies.

Conflict Of Interest: None.

REFERENCES

Cardinale, L., G. Volpicelli, A. Lamorte, J. Martino and A. Veltri. (2012). Revisiting signs, strengths and weaknesses of standard chest radiography in patients of acute dyspnea in the emergency department. J. Thoracic. Dis. 4: 398-407.

Chibane, S., A. Semionov, J. Kosiuk, J. Pressacco, K. Sayegh, G. Giancaspro, A. Khatchikian, P.S. Benvenuto, J. Chin, S. Ghumman and A. Maimani. (2022). Accuracy of patient age estimation from frontal chest radiographs of adult patients. Open J. Radio. 12: 37-48.

Collado-Mesa, F., E. Alvarez and K. Arheart. (2018). The role of artificial intelligence in diagnostic radiology: a survey at a single radiology residency training program. J. Am. Coll. Radio. 15: 1753–7.

Copley, S.J., A.U. Wells, K.E. Hawtin, D.J. Gibson, J.M. Hodson, A.E. Jacques and D.M. Hansell. (2009). Lung Morphology in the Elderly: Comparative Study of Subjects over 75 Years Old versus Those under 55 Years Old. Radio. 251: 566-573.

Coudray, N., P.S. Ocampo, T. Sakellaropoulos, N. Narula, M. Snuderl, D. Fenyö, A.L. Moreira, N. Razavian and A. Tsirigos. (2018). Classification and mutation prediction from non-small cell lung cancer histopathology images using deep learning. Nat. Med. 10: 1559-1567.

Dellios, N., U. Teichgraeber, R. Chelaru, A. Malich and I.E. Papageorgiou. (2017). Computer-Aided detection fidelity of pulmonary nodules in chest radiograph. J. Clin. Imaging Sci. 7:8.

Esteva, A., B. Kuprel, R.A. Novoa, J. Ko, S.M. Swetter, H.M. Blau and S. Thrun. (2017). Dermatologist-level classification of skin cancer with deep neural networks. Nature. 542(7639): 115-118.

Gross, B.H., K.F. Gerke, K.K. Shirazi, W.M. Whitehouse and F.L. Bookstein. (1985). Estimation of patient age based on plain chest radiographs. Canad. Assoc. Radio. J. 36: 141-143.

Hurt, B., Kligerman, S. and A. Hsiao. (2020). Deep learning localization of pneumonia: 2019 coronavirus (COVID-19) outbreak. J. Thorac. Imaging. 35: 87–9.

Ieki, H., K. Ito, M. Saji, R. Kawakami, Y. Nagatomo, K. Takada, T. Kariyasu, H. Machida, S. Koyama, H. Yoshida and R. Kurosawa. (2022). Deep learning-based age estimation from chest X-rays indicates cardiovascular prognosis. Com. Med. 2(1): 159.

Jang, S., H. Song, Y.J. Shin, J. Kim, J. Kim, K.W. Lee, S.S. Lee, W. Lee, S. Lee and K.H. Lee. (2020). Deep Learning-based automatic detection algorithm for reducing overlooked lung cancers on chest radiographs. Radio. 296: 652–61.

Karargyris, A., S. Kashyap J.T. Wu, A. Sharma, M. Moradi T.S. Mahmood. (2019). Age prediction using a large chest X-ray dataset. Med. Imaging. 17: 1-9.

Kido, M., K. Kohara, S. Miyawaki, Y. Tabara, M. Igase and T. Miki. (2012). Perceived age of facial features is a significant diagnosis criterion for age-related carotid atherosclerosis in Japanese subjects: J-SHIPP study. Geriatr. Gerontol. Int. 12(4): 733-40.

Nielsen, B.R., A. Linneberg, K. Christensen and P. Schwarz. (2015). Perceived age is associated with bone status in women aged 25–93 years. Age. 37: 106.

Patyal, S. and T. Bhatia. (2022). Evaluating costal cartilage for sex and age estimation from PA chest radiographs of North Indian population: a retrospective study. Egypt. J. Forensic Sci. 12: 41.

Rajpurkar, P., J. Irvin, K. Zhu, B. Yang, H. Mehta, T. Duan, D. Ding, A. Bagul, C. Langlotz, M.P. Lungren and Ng Ay. (2017). CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning. Comp. Vis. Patt. Recog. 1711: 05225.

Ribeiro, A.H., M.H. Ribeiro and G.M.M. Paixão. (2020). Automatic diagnosis of the 12-lead ECG using a deep neural network. Nat. Commun. 11: 1760.

Sabottke, C.F., M.A. Breaux and B.M. Spieler. (2020). Estimation of age in unidentified patients via chest radiography using convolutional neural network regression. Emerg. Radio. 27: 463-468.

Sim, Y., M.J. Chung, E. Kotter. (2019). Deep Convolutional neural Network– based software improves radiologist detection of malignant lung nodules on chest radiographs. Radio. 182465.

Stern, D., C. Payer, N. Giuliani and M. Urschler. (2019). Automatic age estimation and majority age classification from multi-factorial mri data. IEEE J. Biomed. Health Inform. 23(4): 1392-1403.