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# Accuracy of Patient Age Estimation from Frontal Chest Radiographs of Adult Patients

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## Abstract

**Objective:** The objective of this study is to evaluate the accuracy of patient age estimation from frontal chest radiographs of adult patients. **Methods:** 195 posterior-anterior chest radiographs without significant abnormalities were shown to 5 staff radiologists and 6 radiology residents, who were asked to provide their estimates of patient age to the nearest decade. Real patient age distribution ranged from 16 to 91 years of age. **Results:** On average, correct estimate of patient age decade was made in 22% of cases. Staff radiologists were overall more accurate in their estimations compared to residents. Best accuracy was achieved by the radiologist with the most years of clinical experience, however overall accuracy did not tend to correlate with number of years in practice for staff, nor years of post-graduate training for residents. Overall, patient age was most often overestimated. The least accurate estimates were made for patients younger than 20 years and older than 90. Best accuracy was seen for patients between 50 and 70 years of age. For patients between 20 and 90 years of age, overall estimates were within 11 - 15 years of their true age. There was no significant difference in accuracy of age estimation between radiographs of women and men. **Conclusions:** Average rate of correct age estimation to the nearest decade from normal frontal chest radiographs in our study was 22%. Staff radiologists were more accurate than radiology residents. Best estimates were made for middle-aged patients, and worst for extremes of age.

## Keywords

Age Estimation, Chest Radiography, Radiology Residents

## 1. Introduction

The ability to estimate patient age from chest radiographs can have important implications in daily medical practice. For instance, discrepancies between a person's stated age and the one estimated from the person's chest radiograph may alert the radiologist to the possibility of a mistaken identity, which can occur as a result of clerical error or erroneous image labelling. Indeed, in a Pennsylvania Patient Safety Authority study, 30.1% of radiological errors or "wrong" events in 2009 were patient misidentifications (wrong patient), with 47.4% of these mismatches occurring with radiography studies [1]. Furthermore, this skill might be useful in situations where a patient's identity is unknown or unconfirmed, as could be the case of an unconscious patient with severe disfigurement and lacking identification documents [2] [3]. In the above and similar situations, an age estimate from a chest radiograph can aid in establishing appropriate diagnoses, prognoses and treatment plans [2] [3] [4] [5]. A study at the University of Granada concluded that osteogenic features on digital X-Rays, while not appropriate for metric measurements, may be used as age indicators in the field of Physical Anthropology [6]. While deep learning tools such as those using convolutional neural network (CNN) regressions have been established as highly accurate—and potentially better suited—tools to estimate age in these unidentified patients, CNN models are not readily available nor are they a first-line option in the current healthcare environment [7]. Knowledge of patient age allows the radiologist to avoid overinterpreting expected age-related imaging findings, e.g. degenerative changes of the spine and shoulders [8], or avoid undercalling findings which are normal in the elderly but pathological in the young, e.g. tortuous aorta or coronary calcifications [4].

Chest radiography remains the most used diagnostic imaging modality, with a worldwide average of 236 chest radiographs per 1000 patients obtained yearly [9]. Cheap, widely available, and rapidly performed, chest radiography plays a crucial role in diagnosis and disease monitoring both in the hospital and community settings [10]. Even so, age estimation in thoracic imaging has mainly been studied in the context of CT scans. Only a handful of publications have focused on chest radiography-based age estimation [11]. We managed to identify only one such publication in English-language medical literature, a 1985 study by Gross *et al.*, which found no conclusive correlation between observer experience and accuracy of patient age estimation, but demonstrated statistically significant differences among participants, and a mean overall error of fewer than 15 years [12]. Many changes have occurred in chest radiography in the 35 years since the latter publication, such as the advent of computer and digital radiography, Picture Archiving and Communication Systems (PACS), as well as major reforms to radiology residency training programs. Radiologists in training are receiving increased exposure to more advanced radiological techniques, namely, computed tomography and magnetic resonance imaging, with a potentially reduced exposure to plain films. Accordingly, our study aims to assess modern day radiologists' and radiology trainees' proficiency at estimating patient age from normal chest radiographs acquired with contemporary technology.

## 2. Methods

### 2.1. Permission

This is a retrospective study of anonymized normal chest radiographs collected from our daily worklist and we received an exemption from Research Ethics Board (REB) review from the McGill University Healthcare Centre's Centre for Applied Ethics.

### 2.2. Study Population

A total of 195 chest digital radiography (DR) posterior-anterior images were selected by a fellowship-trained thoracic radiologist with 10 years of experience as a staff physician. The images were obtained from the radiologist's randomly attributed daily reading list at an adult tertiary care centre over a period of two months. The main radiograph selection criterion was the absence of any significant abnormalities, including degenerative changes of the skeletal structures and vascular calcifications. As such, only normal or near-normal chest radiographs were selected for this study. An attempt was made to have an equal representation of radiographs of women and men, as well as a similar distribution across different age groups. Images were retrieved from our hospital PACS as JPEG files. True patient age was defined according to demographic information recorded in the patient's electronic medical chart. All identifying labels were removed and images were exported to a PowerPoint presentation (PPP). Each chest radiograph was randomly attributed a number from 1 to 195 with images placed in this order in the slideshow (**Figure 1**). The demographics of the patients are summarized in **Table 1**.

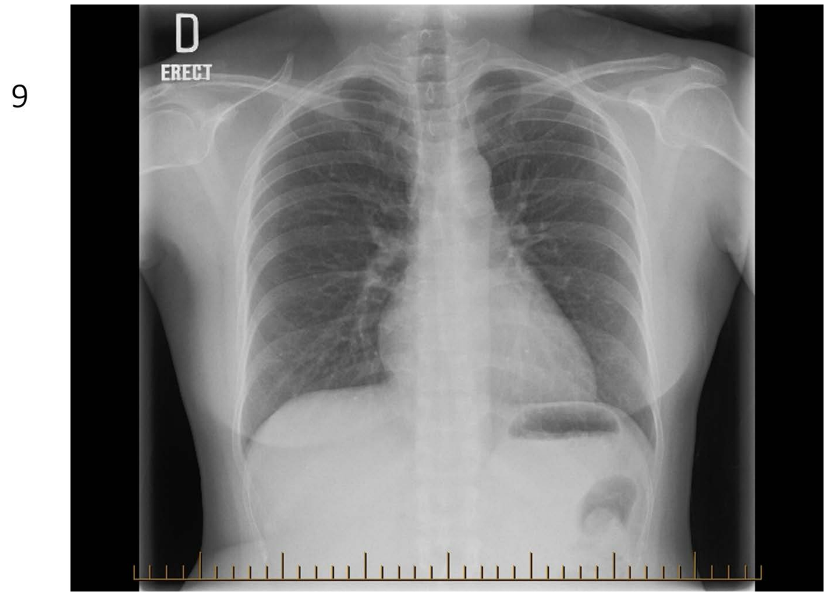


**Figure 1.** Anonymized chest radiograph. Example of an anonymized chest radiograph with a randomized identifying number, as presented in the distributed PowerPoint presentation.

Table 1. Patient demographics.

| Age group (N = 195) | Women (N = 121) | Men (N = 74) |
|---|---|---|
| <20 (n = 19) | 12 | 7 |
| 20 - 29 (n = 25) | 16 | 9 |
| 30 - 39 (n = 34) | 26 | 8 |
| 40 - 49 (n = 40) | 24 | 16 |
| 50 - 59 (n = 30) | 14 | 16 |
| 60 - 69 (n = 20) | 10 | 10 |
| 70 - 79 (n = 15) | 10 | 5 |
| 80 - 89 (n = 10) | 8 | 2 |
| ≥90 (n = 2) | 1 | 1 |

### 2.3. Readers

Readers included five fellowship-trained thoracic radiologists with clinical experience ranging between 6 and 31 years, and six radiology residents at different stages of their radiology residency training (one post graduate year (PGY) 5, one PGY 4, two PGY 3, and three PGY 2). The clinical experience of each reader is summarized in Table 2. All readers were blinded to the patients' demographics and were tasked to estimate patient age to the nearest decade (<20, 20 - 29, 30 - 39 and so on until >90) for each chest radiograph included in the PPP images set. The readers entered their answers in individual Excel spreadsheets.

### 2.4. Data Analysis

Answers from all 11 readers were compiled using Microsoft Excel. Microsoft Excel Visual Basics for Applications was used to extract, sort and analyze the data. This was completed using conditional loops to store the data inside multi-dimensional arrays, particularly for the analysis of estimate discrepancies specific to each age group. Basic statistical calculations were performed to determine accuracy according to individual readers, reader experience and patient gender. This was done through basic arithmetic functions which were inputted into Excel, including summation, division, simple average and weighted average. Metrics used include percentages of correct estimates and weighted average discrepancies from the correct age group, in decades, of the age estimates. For example, if an average discrepancy is 1.30, it would mean that ages for the given category were, on average, over or underestimated by 1.3 decades or 13.0 years. Confidence intervals were determined using small sample t-test statistics, when determining accuracy discrepancy between staff and residents (group count of 5 and 6, respectively). A normal distribution hypothesis with 195 data points (radiographs) was used when determining a weighted average of individual readers' estimate accuracy and estimate accuracy per age group. Accuracy is hereby defined as a qualitative indicator of how close an estimate is to the correct age group (the closer to the correct age group, the more accurate).

Table 2. Readers' level of experience.

| Reader (N = 11) | Experience |
|---|---|
| 1—radiology staff | 31 years |
| 2—radiology staff | 25 years |
| 3—radiology staff | 15 years |
| 4—radiology staff | 10 years |
| 5—radiology staff | 6 years |
| 6—radiology resident | PGY[a] 5 |
| 7—radiology resident | PGY 4 |
| 8—radiology resident | PGY 3 |
| 9—radiology resident | PGY 2 |
| 10—radiology resident | PGY 2 |
| 11—radiology resident | PGY 2 |

[a]PGY = post-graduate year (year of residency).

## 3. Results

Combined results from all 11 readers show that, on average, correct estimate of patient age to the nearest decade across all radiographs was made in 22% of cases (Table 3). Patient age was underestimated in 30% of cases and overestimated in 48%. While residents tended to overestimate age more than staff radiologists, staff radiologists underestimated age more than residents. However, overall, both residents and staff radiologists had more overestimations than underestimations (Figure 2).

Generally, estimate discrepancy from real age ranged from 11 to 24 years (1.1 to 2.4 age groups), depending on the age decade. Estimates were most accurate for middle-age groups, with the weighted average class discrepancy for ages 40 to 59 at 1.16 in contrast to 1.59 and 1.37 for ages 39 and under and 70 and above, respectively.

The most accurate estimates, with an average discrepancy of about 11 years (95% CI, [0.897 - 1.33 decades]) and a correct estimate rate at 26%, were made for the 50 - 59 age group (Table 4, Figure 3). Conversely, the most inaccurate estimates were observed for patients younger than 20 and older than 90 (off by 22 years (95% CI, [1.83 - 2.65 decades]) and 24 years (95% CI, [1.83 - 2.65 decades]) and with a correct estimate rate of 7% and 0%, respectively). For patients aged between 20 and 90 years, age over or underestimations ranged between 11 and 15 years (95% CI, [0.897 - 1.63 decades]). This error range was determined from the maximal and minimal values of average estimate errors per age group, *i.e.* 11.2 years for 50 - 59 age group, and 15.2 years for 20 - 29 age group (Table 4).

There was no significant difference in correct age decade estimation between radiographs of women (n = 1331) and men (n = 813): it was correctly estimated (at ±0 decades) in 21% of chest radiographs of female patients and in 23% of radiographs of male patients.

There was a statistically significant difference in the accuracy of age estimates made by staff radiologists, when compared to residents, with a p-value of 0.025 ($p < 0.05$). Staff radiologists were overall more accurate in their estimations compared to residents, as staff and residents were off by an average of 12.1 years (95% CI, [10.2 - 14.0]) and 15.0 years (95% CI, [12.8 - 17.2]), respectively (Figure 4).

**Table 3.** Accuracy of age estimates by staff radiologists and residents.

| | Correct age (%) | Underestimated (%) | Overestimated (%) |
|---|---|---|---|
| Staff 1 | 61 (31) | 62 (32) | 71 (37) |
| Staff 2 | 46 (24) | 28 (14) | 121 (62) |
| Staff 3 | 42 (22) | 69 (35) | 84 (43) |
| Staff 4 | 29 (25) | 96 (49) | 50 (26) |
| Staff 5 | 41 (21) | 50 (26) | 104 (53) |
| Resident 1 | 39 (20) | 84 (43) | 72 (37) |
| Resident 2 | 29 (15) | 58 (30) | 108 (55) |
| Resident 3 | 31 (16) | 28 (14) | 136 (70) |
| Resident 4 | 43 (22) | 40 (21) | 112 (57) |
| Resident 5 | 41 (21) | 59 (30) | 95 (49) |
| Resident 6 | 47 (24) | 71 (36) | 77 (39) |
| All Staff/Residents | 469 (22) | 645 (30) | 1030 (48) |

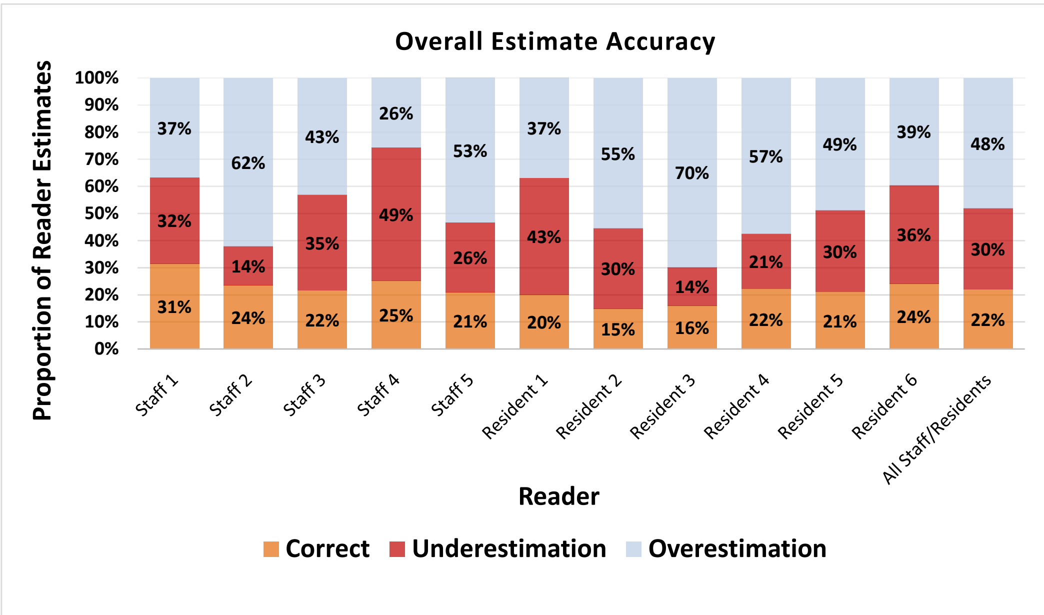


**Figure 2.** Patient age estimate accuracy. Percentage of correct age decade estimations, underestimations and overestimations for each radiology staff and resident reader.

Table 4. Accuracy of age estimates by age groups.

| Estimate error (decades) | Age | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | <20 (n = 208) | 20 - 29 (n = 275) | 30 - 39 (n = 374) | 40 - 49 (n = 440) | 50 - 59 (n = 330) | 60 - 69 (n = 220) | 70 - 79 (n = 165) | 80 - 89 (n = 110) | ≥90 (n = 22) |
| ±0 | 15 | 55 | 89 | 107 | 87 | 56 | 37 | 23 | 0 |
| ±1 | 53 | 101 | 156 | 181 | 150 | 98 | 67 | 46 | 5 |
| ±2 | 53 | 68 | 78 | 107 | 63 | 50 | 48 | 28 | 8 |
| ±3 | 55 | 30 | 36 | 39 | 28 | 14 | 10 | 10 | 5 |
| ±4 | 18 | 14 | 14 | 6 | 2 | 2 | 2 | 0 | 3 |
| ±5 | 14 | 7 | 1 | 0 | 0 | 0 | 1 | 3 | 1 |
| Weighted average discrepancy (decades) | 2.24 | 1.52 | 1.29 | 1.22 | 1.12 | 1.13 | 1.25 | 1.34 | 2.41 |

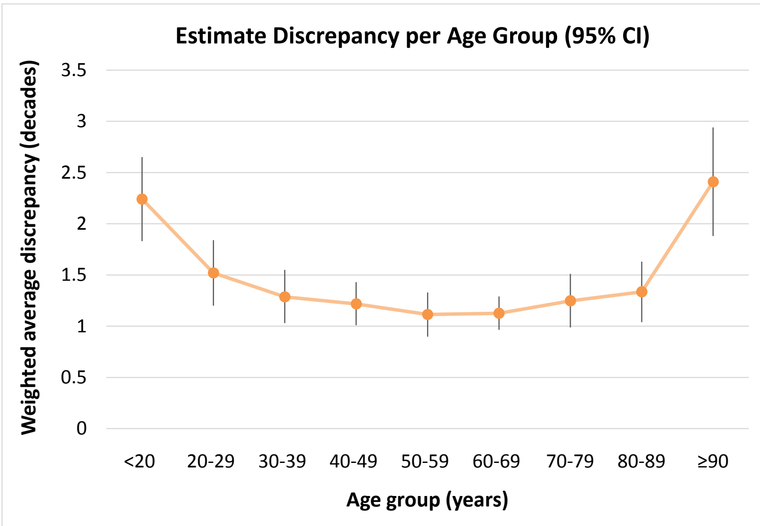


Figure 3. Estimate accuracy per age group. Weighted average of estimate discrepancies (in decades), per age group, for all readers combined.

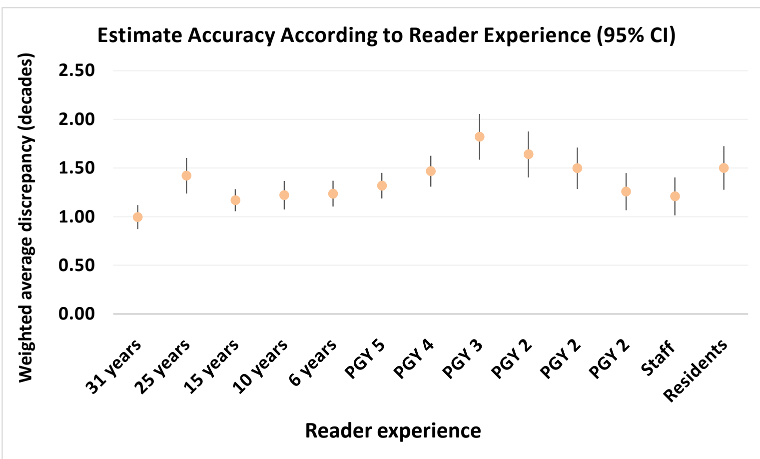


Figure 4. Estimate accuracy according to reader experience. Individual readers' average estimate discrepancy (in decades) for all age groups combined, 95% confidence interval

The highest rate of correct estimates, 31%, and the best overall accuracy, with a weighted average error of 9.9 years (95% CI, [8.8 - 11.1]) was achieved by the staff radiologist with most years of clinical experience (reader 1 in **Table 3**, **Table 5** and **Figure 4**).

We observed no trend in correlation between age estimate accuracy and the number of post-graduate years of radiology residency training (PGY) among resident readers or number of years in clinical practice for staff radiologists (**Table 3**, **Table 5** and **Figure 4**). Residents deviated from true patient age by a greater number of decades (4 or 5) more often than staff, although their rate of correct estimates (at 0 decades discrepancy) was similar to staff. Staff estimates were more accurate as their interval average discrepancy in decades was closer to 0 than residents (95% CI, [1.02 - 1.40] as opposed to [1.28 - 1.72]) (**Table 5**).

## 4. Discussion

Knowledge of patient age can be important in interpretation of chest radiographs. It can help avoid the diagnostic pitfall of describing findings that are deemed normal or common in the elderly as significant pathology, or undercall those that could be expected in the old, but abnormal in the young. It can also help in detecting cases of mistaken identity due to clerical or technical errors and in identification of Jane/John Doe patients. Therefore, being able to estimate patient age from chest radiograph, at least to a correct decade, seems to be a valuable skill.

**Table 5.** Average discrepancy intervals according to reader experience.

| Reader Experience Level | Weighted average discrepancy (decades) | | |
|---|---|---|---|
| | Average | Lower border | Upper border |
| **31 years** | 0.99 | 0.88 | 1.11 |
| **25 years** | 1.42 | 1.24 | 1.60 |
| **15 years** | 1.17 | 1.06 | 1.28 |
| **10 years** | 1.22 | 1.08 | 1.36 |
| **6 years** | 1.24 | 1.11 | 1.36 |
| **PGY 5** | 1.32 | 1.19 | 1.44 |
| **PGY 4** | 1.47 | 1.32 | 1.62 |
| **PGY 3** | 1.82 | 1.59 | 2.05 |
| **PGY 2** | 1.64 | 1.41 | 1.87 |
| **PGY 2** | 1.50 | 1.29 | 1.70 |
| **PGY 2** | 1.26 | 1.07 | 1.44 |
| **Staff** | 1.21 | 1.02 | 1.40 |
| **Residents** | 1.50 | 1.28 | 1.72 |

There are certain well known imaging features that can help to estimate patient age from their chest radiograph: costal cartilage calcifications, changes in the aorta such as tortuosity, calcifications and dilatation, and degenerative changes of the shoulders and spine, amongst others [4] [13] [14] [15] [16]. On the other hand, if a chest radiograph shows no overt manifestations of aging, just how good are radiologists at estimating patient age from a normal chest radiograph?

The last publication on the subject in English-language medical literature dates back to 1985 [11]. Since then, chest radiography technologies for image acquisition, storage and viewing have significantly evolved, as did radiology residency and subspecialty fellowship training programs [17]. In this context, we conducted the present study in order to find out how good present-day radiologists and trainees are at estimating patient age from chest radiographs without significant abnormalities.

We found that, on average, staff radiologists and residents can correctly estimate the decade of patient age in 22% of cases (469 of 1030 plain films). In theory, this accuracy rate is better than chance, which would be approximately 11% (*i.e.* a random choice of 1 of the 9 age groups to choose from). However, since our data classes are unbalanced in number, a more accurate comparison to chance would be measured against the probability of selecting a given age group. Our best accuracy estimates at 26% for the 50 to 59 age group is comparable to a 15% chance of selecting the group at random (330 radiographs in our total group of 2144 radiographs analyzed by our readers). While our most accurate estimates remain better than chance, this is less than the 35% average of correct estimates reported by Gross et *al.* However, the 1985 study differs from our study as it did not mention a selection of cases without obvious abnormalities which might hint to patient's age, did not specify the number of cases in each age category, did not include patients older than 81, and was based on an analysis of both frontal and lateral chest radiographs. The latter point is important as some age-specific imaging abnormalities are more obvious on lateral radiographs, such as degenerative changes of the spine and thoracic aorta changes described above [13] [14] [15] [16]. Our own results suggest that by having a higher proportion of radiographs in age categories between 20 - 70 years improves age estimation accuracy and thus could potentially explain the discrepancy between the results obtained in our study and those obtained by Gross et *al.*

The most accurate estimates in our study were made for patients older than 20 and younger than 90. This observation could be due to the fact that, as specialized radiologists in a tertiary care adult hospital, our readers are not used to seeing radiographs of teenagers, and healthy 90-year-old with near normal chest radiographs, which skewed their responses towards middle-age estimates. Presence of abnormalities usually attributed to the advanced age was used as an exclusion criterion in radiographs selection for our study, which agreeably made age estimation distinctly more difficult and may have also directed estimates to an age group with the statistical expectation of fewer degenerative changes than older age groups [8]. For young and middle-aged adults, we found that our average age estimates were off by 11 to 15 years of their true age, which is similar to what was reported by Gross *et al.* (9 to 14 years). Finally, in our study, staff radiologists tended to be more accurate in patient age estimation than radiology residents. Although the best accuracy was achieved by the radiologist with the most years of clinical experience, the overall accuracy did not tend to correlate with number of years in practice for staff radiologists, nor with years of post-graduate training for residents.

There are a few limitations to this study with respect to applicability of its results to everyday clinical practice. First, we chose to rely on analysis of only frontal chest radiographs, whereas in clinical practice a lateral chest radiograph is often available, which may carry additional visual information that may help with age estimation. Second, the images were presented to the readers in PPP format, which precluded dynamic adjustments of their contrast and intensity, which is routinely done when analyzing images in PACS environment and is helpful in more thorough assessment of subtle radiographic features. Third, this study focused on normal or near-normal radiographs, additionally excluding those with obvious signs of more advanced age, while radiologists tend to rely on the latter (e.g. vascular calcifications) as well as presence of disease (e.g. emphysema, osteoarthritis) when trying to estimate patient age. Finally, as only normal radiographs were selected, the demographics of the study population were skewed towards younger age groups. This may have increased age estimation inaccuracy due to disproportionate number of younger patients included in the study, when compared to a normal clinical practice and to the much lower probability that older patients would have completely normal chest radiographs.

## 5. Conclusion

Although the overall average rate of correct age estimation from a normal frontal chest radiograph in our study was only 22%, for patients older than 20 and younger than 70, the average discrepancy from true age ranged between 11 and 15 years, depending on the age, which is a reasonable approximation in cases of mistaken identity or patients with unknown age. Staff radiologists were more accurate at estimating patients age than residents. It would be interesting to further this academic exercise by juxtaposing our findings with artificial intelligence tools and potentially optimize the accuracy of patient age estimation from chest radiography.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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