Short Communication

THE APPLICATION OF NEW TECHNOLOGIES IN DIAGNOSING OCCUPATIONAL ASBESTOSIS*

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Medical experts have increasingly been relying on modern computer technologies in performing their work. This paper opens with a brief description of the advantages of computer technologies (compression of a digital image, its filing, transfer and formatting), and their bearing on the accuracy of diagnosis. The aim of this study was to assess the reliability of modern technologies, particularly in diagnosing asbestosis. The study included subjects employed in asbestos plants in Ploče, Croatia. The advantages of the computer aid were viewed in relation to intraobserver's and interobserver's error in the reading of X-ray. Independent radiologists disagreed in about 30 of 223 X-ray readings on which they based their diagnosis (healthy or not healthy).

KEY WORDS: *computer-aided diagnostics, computer technology, ILO classification, pulmonary X-ray*

Many human occupations have been computerised thanks to the progress made in computer technologies in the last decade of the 20th century. A most challenging area in that respect has been medicine. Computer technology has made many tasks in medicine easier, but there is still a lot of room for further development and improvement. Modern computer methods for telemedicine, PACS (Picture Archiving Computer System), and HIS (Hospital Information System) are being used more and more in information transfer, as well as in aiding the process of diagnosing. This paper investigates the advantages of computer diagnosis which are illustrated by examples of X-ray reading errors and analyses the influence of certain computer technologies in telemedicine and information systems on the accuracy of diagnosis. The aim of our study was to assess the reliability of modern technologies in that respect, applying them in diagnosing asbestosis.

Asbestos is a group of silicates of fibrous structure. Its diameter varies from 0.5 to 15 μm and the length from 15 to 100 μm. Three minerals have mainly been used for asbestos production: chrysotile, amosite and crocidolite. Asbestos has found application in a number products in the last century, and its content has varied on the type of the product, that is, from 1 to 100 per cent (1).

Inhaled asbestos causes significant health problems: pulmonary and/or pleural asbestosis, mesothelioma and lung cancer (1-3). The diagnosis of these diseases relies on clinical, radiological, functional and other findings, provided, of course, that asbestos exposure has been positively established (4). Basic radiological examinations include chest radiographs performed in a standard PA position (5).

A radiologist compares the patient's X-ray with the X-rays provided by ILO. The ILO classification is used in epidemiological research, health surveillance and for clinical purposes, but it does not imply legal definition of pneumoconiosis for compensation purposes and does not define work capacity (6).

Like in many other diseases, prevention and education are very important for controlling asbestosis. Unfortunately, relevant education is limited

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to the specialists in occupational medicine and no one else involved in safety at work. Workers exposed to asbestos know little about the adverse effects of smoking, the development of pulmonary fibrosis and the risk of pulmonary carcinoma (7).

The aim of this study was to assess the reliability of modern technologies, particularly in diagnosing asbestosis. In the process, an emphasis was given to interobserver errors.

SUBJECTS, MATERIALS AND METHODS

This study included workers employed in the asbestos plant in Ploče, Croatia. It mainly relies on the findings of a regular examination performed in Dubrovnik and Ploče in 1999. X-ray reading is a delicate procedure inasmuch as a single radiologist may come up with different interpretations of the same radiograph on different occasions (8). From 223 X-rays of 129 male and 94 female workers, we singled out those in which the readings by three independent radiologists disagreed. According to the international criteria, adopted in Helsinki in 1997, these subjects had occupational pulmonary asbestosis.

The use of computer technology may prove very helpful in reducing these disagreements. The proposed algorithm in Figure 1 illustrates the use of computer

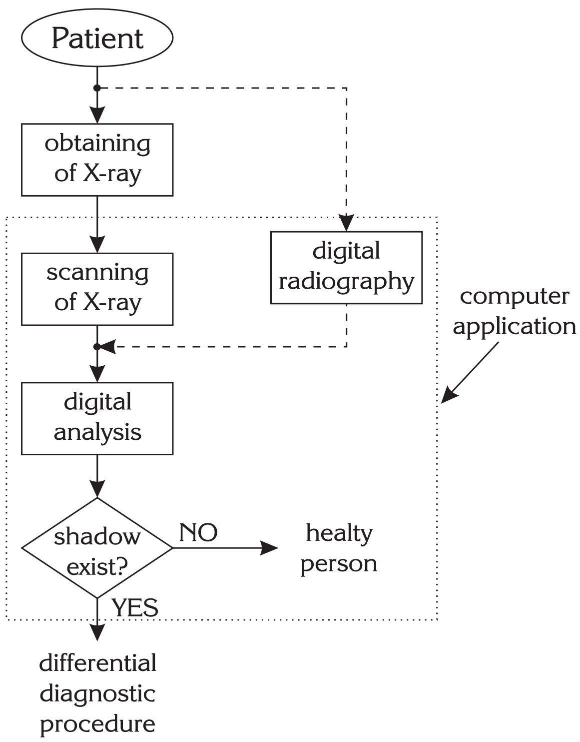

Figure 1 *Computer help in diagnostic procedure*

technology in diagnostic procedure. Of course, how useful computers are depends on software they use. If the computer programme finds only shadows, then it can not single out patients according to the Helsinki criteria, but if it finds shadows according ILO categories, then it can offer an objective interpretation of the patient's condition. In contrast, human experts always partly rely on subjective experience, which is the main reason for misinterpretation of an X-ray.

Nowadays it is possible to obtain very accurate digital X-ray images. However, when the x-ray is not available in digital format, it is very important to make it digital. An X-ray film can be scanned using a high-quality scanner. In this study we used photography to obtain better results. The method consists of photographing the chest radiograph and then scanning the photography. However, it is not easy to preserve all medical information since this method is too intricate to be used in everyday practice. It can be recommended only for scientific purposes.

Since the shadows (indicating asbestosis) are, in fact, grey tones in a digital image, it was logical to introduce a histogram criterion for quick diagnosis (9, 10). However, histograms are not totally reliable because the same grey tones can represent different diseases or phenomena. We used a well-known MATLAB® software package for image analysis. First we put the scanned radiograph into a matrix and then analysed the histogram. Depending on whether the histogram showed shadows we marked the patient's radiograph as either "healthy" or "not healthy". This procedure can be improved by using thresholds for ILO categories.

In our earlier studies (9-18), we investigated the influence of image compression on diagnosis. We used different types of compression and different image formats to see if information was lost in processed images. Of course, original and reconstructed images are not expected to be completely identical, but the question is whether these changes influence the diagnosis. Radiologists read the images before compression and after reconstruction, to evaluate the method. In this study, we used the help of one to three radiologists, depending on the task they were asked to do.

RESULTS

Table 1 shows the differences in X-ray readings between radiologists. The diagnoses differred in about 62 % of cases.

Table 1 *Absolute number of disagreements in X-ray readings in the examination from 27 August to 8 November 1999.*

3 same ILO characterization	2 same, 1 different ILO characterization	3 different ILO characterization	Interobserver errors	Total number of cases
85	120	18	138	223

Table 2 *Observed changes in X-rays*

Observed changes	ILO 0/0	Pulmonary changes	Changes in pleura	Mixed changes	Changes not related to asbestos	Total
Number of subjects	67	35	40	74	7	223

Table 2 shows the observed pulmonary changes in chest X-rays. Of three readings, the one with the greatest changes was used. The same is true for data in Table 3. These data show that changes in the lung are usually concomitant with changes in the pleura. This is why combined changes are the most frequent, followed by isolated X-ray changes in the lung and pleura. Changes in the pleura accounted for about 18 % of all cases and combined changes accounted for 33 % of all cases.

With regard to asbestos-induced diseases, all three radiologists confirmed that 67 patients were totally healthy according to the International Labour Organization classification (ILO 0/0). In comparison, MatLab computer software without thresholds detected changes in more patients' X-rays than did radiologists. These changes are not visible by human eye, but it is possible to predict the progress of the disease if occupational exposure to asbestos continues. However, these changes can not be verified as a disease because they are too small to be qualified according to ILO classification.

There were several interesting cases which included interobserver errors, such as for patients shown in Table 4.

Let us take the last case, N. V. (date of birth 1958) as an example. The diagnoses by three independent radiologists date from 23 August 1999. Figure 2 shows a part of her scanned X-ray. It is obviously a low-quality scan, but it was good enough to apply

Table 3 *ILO classification of subjects*

Pulmonary changes caused by asbestos (N=102)						
ILO category	**0/0**	**0/1 s/s**	**0/1 s/t**	**1/1 s/s**	**1/1 s/t**	
No. of subjects	67	25	4	1	5	
Changes in pleura caused by asbestos (N=40)						
ILO category	**1a**	**2a**	**3a**	**1b**	**2b**	
No. of subjects	29	6	3	0	2	
Mixed changes (N=74)						
ILO category	**0/1 s/s, 1a**	**0/1 s/t, 1a**	**1/1 s/s, 1a**	**1/1 s/t, 1a**	**0/1 s/s, 2a**	**0/1 s/t, 2a**
No. of subjects	30	1	5	4	10	1
ILO category	**1/1 s/s, 2a**	**1/1 s/t, 2a**	**0/1 s/s, 3a**	**0/1 s/t, 3a**	**1/1 s/t, 3a**	**1/2 t/t, 3a**
No. of subjects	1	3	6	1	1	1
ILO category	**0/1 s/s, 1b**	**0/1 s/t, 1b**	**0/1 s/s, 2b**	**0/1 s/s, 3b**	**1/1 s/s, 3c**	**1/1 s/t, 3c**
No. of subjects	2	1	2	3	1	1

N=total number of subjects
Categories of small opacities: 0 - opacities absent or les profuse than in category 1; 1 - small opacities definitely seen but few in number; 2 - numerous opacities with normal lung vasculature still visible, 3 - very numerous where lung vasculature is partly or totally obscured.
Each category is indicated by two numbers (the first is the category finally chosen, the second is the alternative category considered).
Small irregular opacities: s - fine irregular or linear opacities; t - moderately coarse irregular opacities.
Thickness of pleural opacities: a - maximum thickness is 5 mm; b - between 5 and 10 mm; c - greater than 10 mm.
Pleural involvement: 0 - not present; 1 - the total length of uni- or multifocal pleural thickening does not exceed a quarter of the length of the lateral chest wall; 2 - the total length does not exceed half the length of the lateral chest wall; 3 - the total length exceeds half length of the lateral chest wall.

Table 4 *Disagreements in X-ray readings between three radiologists*

Patient		Radiologists		
Initials	Sex	First	Second	Third
N. D.	F	0/0	0/0	0/1 s/s RL, LL
R. P.	M	0/0	0/0	0/1 s/s RM, RL, LM, LL
G. B.	M	0/0	0/0	0/1 s/s RL, LL
L. V.	M	1/1 s/s RM, RL, LM, LL, pt: 1aR, 1aL	0/1 s/s, RL, LL, pt: 1aR, 1aL	0/1 s/s RL, LL, pt: 2aR, 2aL
M. Č.	F	0/1 s/s RL, LL	0/0	0/0
Z. G.	F	0/1 s/s, pt: 1aR, 1aL	0/0	0/0, pt: 1aR, 1aL
Ž. T.	M	0/1 s/s RL, LL, pt: 3aR, 3aL	0/0, pt: 3aR, 3aL	0/0 3aR, 3aL
M. V.	F	0/0	0/0	0/1 s/s RL, LL
V. M.	F	0/0, pt: 1aR, 1aL	0/1 s/s RM, RL, LM, LL, pt: 1aR, 1aL	0/0, pt: 1aR, 1aL
I. R.	F	0/0	0/0, pt: 1aR, 1aL	0/1 s/s RL, LL
Z. M.	M	0/0	0/0, pt: 1aR, 1aL	0/1 s/s RM, RL, LM, LL
A. Ž.	F	0/1 s/s RM, RL, LM, LL	0/0	0/0
J. P.	M	0/0 pt: 1aR, 1aL	0/0 pt: 1aR, 1aL	0/1 s/s RL, LL
J. B.	F	0/1 s/s RL, LL, pt: 1aR, 1aL	0/0, 2aR, 2aL	0/0
K. B.	M	0/0	0/0	0/0, pt: 1aR, 1aL
N. V.	F	0/1 s/t	0/0	0/0.

Categories of small opacities: 0 – opacities absent or les profuse than in category 1; 1 – small opacities definitely seen but few in number; 2 – numerous opacities with normal lung vasculature still visible, 3 – very numerous where lung vasculature is partly or totally obscured.
Each category is indicated by two numbers (the first is the category finally chosen, the second is the alternative category considered).
Small opacities: p - small rounded opacities up to 1.5 mm in diameter; s – fine irregular or linear opacities; t – moderately coarse irregular opacities.
Thickness of pleural opacities: a – maximum thickness is 5 mm; b – between 5 and 10 mm; c – greater than 10 mm.
Pleural involvement: 0 – not present; 1 – the total length of uni- or multifocal pleural thickening does not exceed a quarter of the length of the lateral chest wall; 2 – the total length does not exceed half the length of the lateral chest wall; 3 – the total length exceeds half length of the lateral chest wall.
Lung zones in which the opacities occur: RU, RM, RL, LU, LM, LL. Each side is divided into upper, middle and lower zones.

histogram analysis. Two radiologists diagnosed the patient as healthy, and one disagreed. In this case, the computer may prove helpful. We applied computer analysis using MatLab to get an objective result. Since there were shadows consistent with asbestos exposure (histogram criteria has been described earlier, see ref. 10, 11, 15), computer-based diagnosis corroborated the opinion of the radiologist who saw changes in the pulmonary X-ray of the patient.

We used the photography method described above to transfer the X-ray images into digital format (see Figures 3a, b, c, and d). The original images were on low-quality films, and the radiologist pointed out that the scanned images seemed of better quality than the originals.

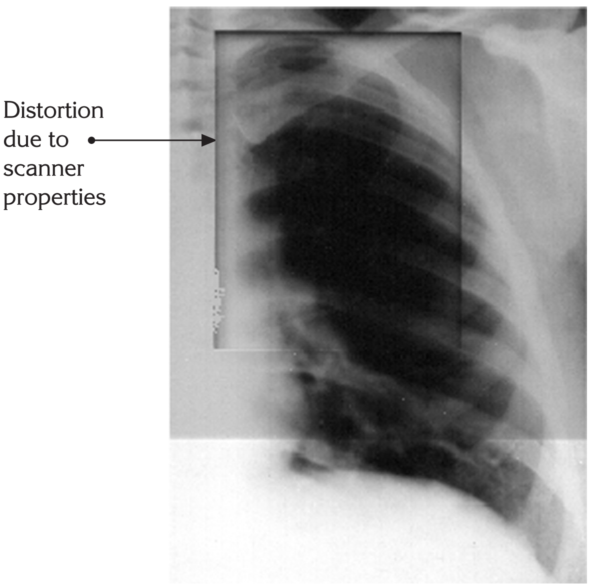

Figure 2 *An example of a scanned X-ray with unsuitable scanner*

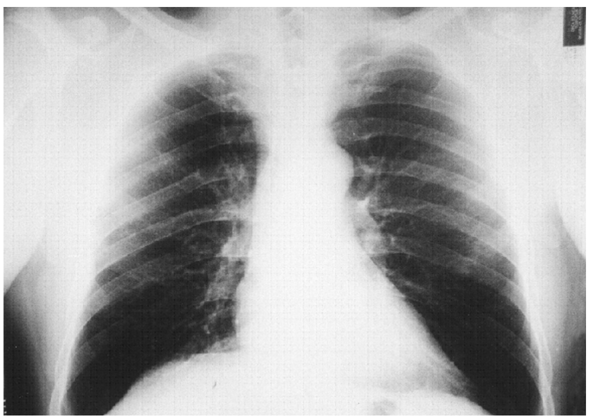

Figure 3a

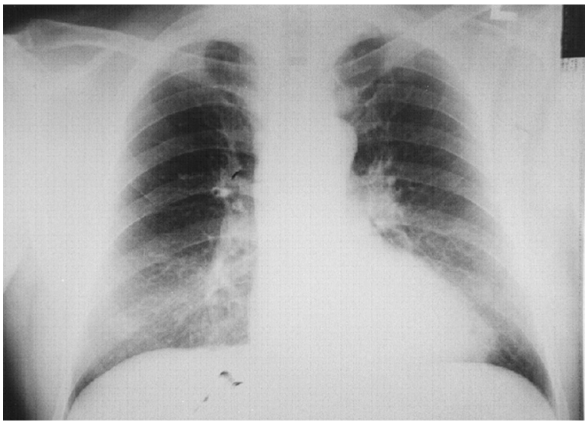

Figure 3b

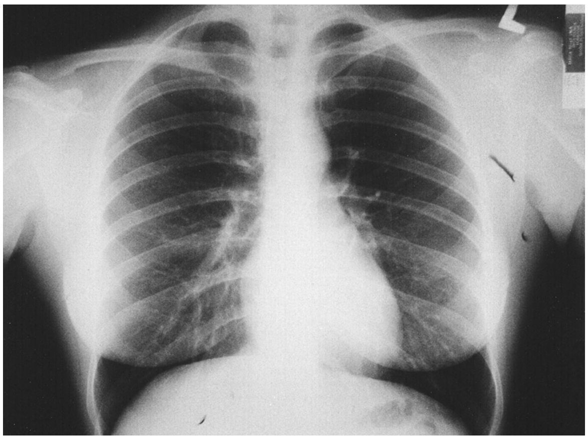

Figure 3c

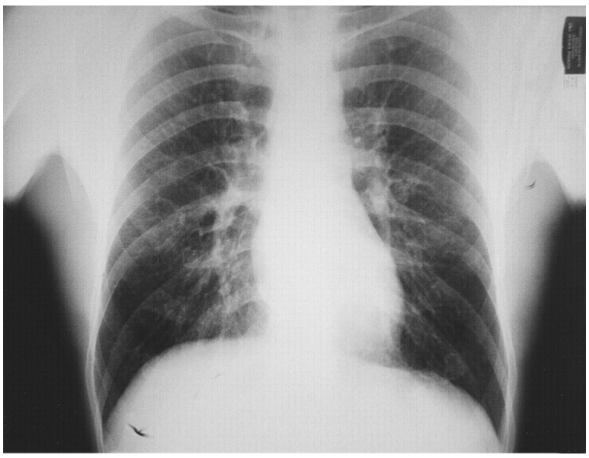

Figure 3d

Figures 3a-3d *Examples of scanned images using the photography method*

Different image formats can affect medical information they contain. Format using compression can alter the content of an image. However, no essential errors were found in ten X-ray images of subjects with the confirmed disease using wavelet compression (with Haar wavelets), viewed by a single radiologist before compression and after decompression. It is worth mentioning that the images can be distorted if zoomed too much, but in normal view, the difference was not noticeable.

We used the bitmap (BMP) and tagged image format (TIF) which do not change the content of an image because there is no processing involved, preserving thus the medical information.

DISCUSSION

The ILO classification of 22 radiographs was 1/1 and of one 1/2. According to the international criteria adopted in Helsinki, these subjects had occupational pulmonary asbestosis. Former criteria for the recognition of this disease in the Republic of Croatia were considerably lower.

Many speculations and legal problems have arisen due to a confusion in criteria for the diagnosis of occupational asbestosis. A definitely negative X-ray reading includes categories ILO 0/- and 0/0. However, 0/1 is questionable for a diagnosis of occupational disease. ILO categories 0/1, 1/0, 1/1, 1/2 were deemed insufficient for confirming occupational asbestosis in former Yugoslavia in 1985 and 1988. Later thresholds for the acknowledgment of occupational asbestosis were less strict, and changed from one scientific meeting dedicated to this issue to another. Today, a positive reading is considered to be ILO 1/0, as agreed in Helsinki in 1997. Until then, the positive finding was considered ILO 0/1, that is, for a few years. This is why some workers are considered to have occupational asbestosis and others not, although their findings are ILO 0/1. This confusion has cost a lot of money (8).

In Table 3, 67 examinees were diagnosed ILO 0/0, that is, as "totally healthy". As no subject was diagnosed ILO 0/-, it is possible that our radiologists confused 0/- and 0/0 in some cases.

The computer reading of a digital image depends on a number of factors such as scanning conditions, the properties and the quality of the scanner and of the film, and so on. This is why digital radiography is more reliable, as it does not involve as many variables. However, there where digital radiography too expensive, a relatively good scanner could generally prove sufficient for computer processing, provided that the film is of high-quality.

Computer-based diagnostic procedures have not been tested long enough to be used as the only evaluation method for a patient's condition, but they can help to resolve doubtful readings. An example of such computer diagnostics procedure is described above in the case of N. V. Further research could lead to the implementation or discarding of the histogram criterion.

To conclude, changes in a radiograph than human eye, and can be used to predict the development of a disease in its early phase. This is the main advantage of the computer in disease prevention and early diagnostics. However, data communication and computer systems are far from error-free. This is why every step in the application of an information technology needs to be carefully monitored.

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Sažetak

UTJECAJ NOVIH TEHNOLOGIJA NA DIJAGNOSTIKU PROFESIONALNE AZBESTOZE

U ovom su radu prikazani primjeri intraopserverskih i interopserverskih pogrešaka u očitanju rendgenskih slika te na njima objašnjena prednost računalne dijagnostike. Ispitan je utjecaj nekih suvremenih računalnih tehnologija (kompresija i arhiviranje digitalne slike, prijenos slike preko Interneta, format digitalne slike) na ispravnost dijagnoze. Cilj je ispitivanje pouzdanosti suvremenih tehnologija. Ispitanici su radnici bivše tvornice azbestnih proizvoda iz Ploča. Iz skupine od ukupno 223 radnika i radnica izdvojeni su zanimljivi primjeri gdje tri neovisna očitanja nisu identična. Ti su slučajevi ispitani računalnim programskim paketom MatLab. Računalni rezultati uspoređeni su s očitanjem nezavisnih radiologa. S ILO-prožetošću 1/1 nađena su 22 ispitanika, a s 1/2 samo 1 ispitanik. Prema međunarodnim kriterijima prihvaćenim u Helsinkiju, to su ispitanici kod kojih bi se radilo o razvoju profesionalne azbestoze pluća. U drugom dijelu rada uspoređeni su standardni plućni radiogrami po ILO-klasifikaciji prije i poslije primjene neke od suvremenih računalnih tehnologija.
Suvremene računalne metode imaju mjesta u standardnim postupcima dijagnostike bolesti pluća uz standardne radiograme pluća po ILO-klasifikaciji, a bez za sada radiološki široko prihvaćenih metoda, kao što su kompjutorizirana tomografija visoke rezolucije. Takve metode (poput CT-a) mogu se primijeniti u individualnim slučajevima, što je važno zbog cijene metode, dok se za širu primjenu može rabiti samo standardni radiogram, jer to zadovoljava epidemiološko istraživanje.

KLJUČNE RIJEČI: *dijagnostika potpomognuta računalom, ILO-klasifikacija, plućni rendgenogram, računalna tehnologija*

REQUESTS FOR REPRINTS:

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