Can Paper Replace Laser Film to Communicate the Results of Wrist Radiographs in Trauma Cases? A Reproducibility Study of the Reading of Wrist Trauma Case Radiographs on a PACS Workstation, Laser Film, and Paper

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Abstract The main goal of this study was to determine the reproducibility of the reading of wrist trauma case radiographs using three different media: laser film, a picture archiving and communication systems (PACS) workstation, and paper with an optimized layout. The study was conducted retrospectively in 200 consecutive patients consulting at the emergency department for wrist trauma and who underwent wrist X-ray investigation using a computed radiography system. There were 82 men and 118 women. The mean age was 48.3 years (16–95 years). Our institutional review board does not require patient approval or informed

consent for retrospective review of case records. The readings were made by two independent readers who analyzed the 200 patient radiographs consecutively in one session for each type of media: paper, laser film, and on a PACS dual-screen workstation. The inter-reader agreements were substantial or almost perfect, with kappa values of 0.83 (0.76–0.90) for the PACS, 0.83 (0.76–0.90) for film, and 0.80 (0.72–0.87) for paper. The inter-technique agreement was almost perfect in all cases. There is a high interobserver agreement between PACS, laser film, and paper readings for wrist trauma cases. With a layout of one radiograph on each sheet, paper could replace laser films to communicate the results of wrist radiographs in trauma cases for outpatients.

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Introduction

The widespread installation of picture archiving and communication systems (PACS) has changed working methods, and today, the reading of radiological images on screen is largely accepted [1–3]. However, in France, PACS at different institutions are not yet connected, and physicians rarely work in the health facility concerned. In addition, printing of images is required for the payment of the radiological procedures. For these reasons, the use of film has not been superseded in France at least for standard radiography.

For financial and practical reasons, paper in association with CD-ROM burning is now used to communicate scanner and MRI data. Due to the financial and economic crisis, which has led to a reduction in reimbursement for radiology

by the French health system, the last bastion of resistance, radiography, has also succumbed to printing on paper. The low intrinsic quality of paper compared to laser film [4, 5] has resulted in resistance on the part of referring physicians, increased in some centers by the layout of several images on a single sheet, which reduces the resolution of images.

The aim of this study is to determine if, after optimization, the interobserver reproducibility between paper, laser film, and PACS workstation reading is sufficient to justify using paper as a communication tool. The ancillary objective was to quantify the loss of image quality of paper compared to laser film or PACS workstation in order to optimize the layout of printed paper.

Material and Methods

A preliminary study on a phantom was conducted prior to the clinical study in order to determine the image quality of the paper used for radiographic purposes compared to laser film and the PACS workstation image and to determine a layout for paper printing of wrist radiographs which could yield a similar spatial resolution to laser film.

Preliminary Study

The phantom used was the IBA Dosimetry Phantom Digi 13 (Siemens), normally used for quality assurance in digital and computed radiography (http://www.medical.siemens.com/webapp/wcs/stores/servlet/ProductDisplay~q_catalogId~e_-11~a_catTree~e_100010,1012315,1014425,1030123,1030140,1014373~a_langId~e_-11~a_productId~e_20779~a_storeId~e_10001.htm). The phantom includes low-contrast objects, comprising aluminum disks with a diameter of 10 mm, producing contrasts of 0.8, 1.2, 2.0, 2.8, 4.0, and 5.6 % at 70 kV, for determination of contrast resolution. It also includes a resolution test (lead foil), 0.6–5.0 lp/mm, rotated 45° for checking spatial resolution. A radiograph was taken and printed with the technique described above. The low-contrast resolution was evaluated on a scale of 0 to 6 depending upon the number of low-contrast disks detected. The spatial resolution was determined by the number of line pairs visible. Two readers (an Musculoskeletal (MSK) fellow and a senior MSK radiologist) independently read the test radiographs on the three different media. The reading was carried out in the same order by each reader: first on paper, then laser film, and finally on a PACS black and white cathode ray tube dual-screen workstation with a display resolution of 2,560×1,024 pixels.

The PACS workstation reading proved to be superior to paper and film for low-contrast resolution with an average score of 6/6; the film was superior to paper with an average score of 4/6 versus 3.5/6 (Table 1). The ranking was the same for spatial resolution performances with mean values of

Table 1 Results of the test tool reading by two readers for the three media types

	Low contrast			Spatial resolution (line pairs/mm)		
	PACS	Laser film	Paper	PACS	Laser film	Paper
Reader 1	6	4	4	3.7	3.4	2.2
Reader 2	6	4	3	3.4	3.1	2.2

3.55 lp/mm for the PACS image, 3.25 lp/mm for the hard copy, and 2.2 lp/mm for paper. Therefore, the images printed on paper had to be at least 48 % larger than those printed on laser films.

Population

This study was performed in the trauma center of a university hospital outside the USA, and the institutional review board does not require patient approval or informed consent for retrospective review of case records.

The study was conducted retrospectively in 200 consecutive patients consulting at the emergency department for wrist trauma and who underwent a wrist X-ray evaluation including four to six radiographs. The different cases were obtained by selecting “wrist radiographs” and “emergency radiology room” in the PACS. There were 82 men and 118 women. The mean age was 48.3 years (16–95 years).

After clinical examination by the emergency physicians, the patients underwent wrist X-rays including four to six radiographs depending upon the clinical findings. The four-view protocol included a postero-anterior view, a lateral view, a semi-supinated oblique view, and a postero-anterior clenched fist stress view. In cases of suspected scaphoid fracture, two additional scaphoid views were taken according to the usual guidelines [4].

Technique

The radiographs were taken in a Rad/fluoro room with an Axiom Iconos R200 (Siemens, Erlangen, Germany) using a small focal spot tube (0.6 mm), 55 kVp, and 7 to 10 mAs setting. They were acquired using a computed radiography system (AGFA DLR with an ADC compact-type digitizer and MUSICA advanced image processing) and sent to the PACS system (Impax version 5.3). They were printed on 20×25 cm format laser film using a Drystar 2000 printer (AGFA) with a layout of two images on a film. They were also printed on 160 g A4 paper using a Xerox WorkCentre M24 with a resolution of 600×600 ppi with a layout of one image per film.

Analysis

The readings were made by two independent readers who analyzed the 200 patient radiographs consecutively in one session for each type of media. The reading was carried out in the same order by each reader: first on the paper, then the laser film, and finally the PACS workstation. The media were those used for the preliminary study. Name, sex, age, and clinical history of the patients were available, as they should always be when reading X-rays. Patients were presented in random order and there was a period of at least 1 week between each reading session. Reader number 1 was an MSK radiologist with 3 years of experience, and reader number 2 was a resident with 6 months of experience in musculoskeletal imaging. The readers could choose between six types of response: radius fracture, scaphoid fracture, other fracture, wrist instability, wrist dislocation, and normal. Multiple choices were possible. If the reader had a doubt about fracture, the diagnosis of fracture was retained because, in many institutions, a suspected fracture or a non-displaced fracture is initially treated in the same manner (cast or plaster). This is particularly the case for scaphoid fractures. The final diagnoses of the readers were also

recorded. However, the type, grade, and displacement of the fractures were not analyzed in our study.

Statistics

The inter-reader agreement was determined for each method and the inter-technique agreement was calculated using Cohen's kappa method [5]. A kappa of 0–0.20 was considered as slight agreement, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement. The 95 % confidence interval was also calculated.

Results

For reader 1 on the PACS, the following were diagnosed for the 200 patients: 19 radius fractures, 16 scaphoid fractures, 7 other fractures, 3 wrist instabilities, 2 dislocations, 17 radius fractures associated with another fracture (ulna fracture in all cases) and 1 scaphoid fracture associated with a scapholunate dissociation, 3 radius fractures with scapholunate dissociation,

Fig. 1 A 44-year-old woman with an undisplaced scaphoid fracture (*arrow*). **a** PACS image. **b** Laser film. **c** Paper print

and 3 other combinations (Figs. 1, 2, 3, and 4). For 135 patients, radiographs were considered normal (Table 2). The inter-reader agreements were substantial or almost perfect with kappa values of 0.83 (0.76–0.90) for the PACS, 0.83 (0.76–0.90) for the films, and 0.80 (0.72–0.87) for the paper. The inter-technique agreement was almost perfect in all cases (Table 3).

Discussion

PACS have a number of advantages compared to traditional reading of radiographs on film. For example, easier image and report access, improved management of examinations with fewer being lost or uninterpretable, and cost reductions [6, 7]. There is also an increased range of tools available to the radiologist, such as windowing or zoom, which facilitate most notably the study of thoracic radiographs although it does not appear to bring advantages over film for the detection of wrist injuries and in particular scaphoid fractures [8]. Youmans et al. showed that digitized images displayed on a workstation may not be adequate for the diagnosis of non-displaced fractures; however, Kundel et al. found that, in the emergency department, soft copy interpretation (workstation) is as reliable as hard copy interpretation (printed films) [9, 10]. Despite the initial controversies, computed radiography and digital radiography are nowadays the only available techniques with

which to perform standard radiography, and PACS are the best systems with which to distribute and read those images.

Most institutions with a PACS want to move towards a completely filmless system. This is usually easy to achieve for inpatients. However, data communication with the outside world will remain more challenging, as long as large-scale Web-based enterprise PACS and electronic patient records with image distribution are not fully installed. For outpatients as well as for patients transferred to other hospitals with no inter-hospital PACS connection, CD-ROM is adequate to transmit CT scans or MR examinations. However, the dedicated high-speed CD-ROM burning systems necessary to deal with the huge number of exams are not available in all institutions for plain films. Besides, for clinicians, reading CDs can be cumbersome and time consuming [11, 12].

Therefore, until recent years, laser films were still printed for standard radiography in outpatients. Hardcopies were also used in case of PACS dysfunction. Laser films remain quite costly (printer costs and films costs) although the total cost depends upon the number and type of the printers as well as the number of films used per year (the price is usually lower when a large number of films is used). The cost for each laser film is approximately 1.00€ in France.

On the other hand, paper printers are already available; as in many institutions, they are widely used for CT scan or MRI and sometimes for office applications at the same time

Fig. 2 A 19-year-old woman with a proximal undisplaced scaphoid fracture (*arrow*). **a** PACS image. **b** Laser film. **c** Paper print

Fig. 3 A 41-year-old woman with an extra-articular, undisplaced distal radius fracture. **a** PACS image. **b** Laser film. **c** Paper print

Fig. 4 A 70-year-old man with an unstable intra-articular, undisplaced distal radius fracture and an undisplaced ulnar styloid fracture. **a** PACS image. **b** Laser film. **c** Paper print

Table 2 Results of the 200 radiographic readings by readers 1 (R1) and 2 (R2)

	Laser film R1	Laser film R2	PACS workstation R1	PACS workstation R2	Paper R1	Paper R2
Radius fracture	19	24	19	25	22	22
Scaphoid fracture	15	10	16	14	17	10
Wrist instability	0	0	3	0	0	1
Dislocation	0	1	2	0	0	1
Other fracture	7	8	7	9	7	8
Normal	135	138	135	130	133	138
Radius fracture + other fracture	17	15	17	17	14	16
Scaphoid fracture + wrist instability	1	0	1	1	1	1
Radius fracture + wrist instability	3	1	3	2	3	1
Other combinations ^a	3	3	3	2	3	2

^a Trans-scaphoid perilunate dislocation, fracture of radius + fracture of scaphoid + other fracture

[13–15]. The cost of each paper print is approximately 0.05€ in France. For our study with 200 patients, the total cost for laser films was 400€ while the total cost for paper print was 40€. Of course, cost saving will be really effective only if paper printing being applied to all outpatients' radiographies. Finally, these printers can easily be installed everywhere in the hospital, for example, in the emergency department, thus avoiding the transportation and delivery of the films. The image quality of paper prints is inferior to that of laser films [16]. However, in a study using CT scans, Bley et al. found it sufficient for the documentation of radiologic findings for most purposes [17]. For these reasons as well as for practical reasons, paper films have superseded laser films in France for CT scan and MRI for data communication in association with CD-ROMs.

Due to the economic and financial crisis, payment for radiographs by the French health system has decreased, thus pushing radiologists to reduce the costs. Most private radiology services and some public hospitals are now using printed papers instead of laser films for communication with referring physicians. However, the image quality is probably more critical for plain film than for other imaging techniques, and the consequences of reading on paper have not yet been clearly assessed. The objectives of our study were to quantify the loss of image quality of paper compared to laser film or PACS workstation and determine if it affects the readings in a large number of wrist trauma cases. We show that despite a definite loss of spatial resolution on paper and a high number

of diagnostic categories, the inter-reader as well as the inter-technique agreements were substantial or almost perfect. Therefore, paper could replace plain film to communicate the results of wrist radiographs in trauma cases. Our findings differ from those of Liang et al. who compared dry laser printing to paper printing in full-field digital mammography and who recommend not using a paper printer because of a lack of detectability of clustered microcalcifications [18]. Schueller et al., who compared the image quality of a wet laser printer with that of a paper printer for full-field digital mammograms, also reported lower image quality on paper, which should not be used for this application [19]. The discrepancy with our results might be explained by the fact that mammography requires both high spatial resolution and high low-contrast resolution. The combined reduction of these two quality factors with paper would affect the results of mammography more than that of bone radiographs where low-contrast detectability is not a key factor for fracture identification. Another reason might be that in our study the size of the printed images on paper was larger than those printed on laser films. In fact, the key image quality factors of the different media for fracture detection remain debatable. In Doyle et al., there was no difference in the accuracy of observer performance for the detection of wrist fractures with a PC compared with a PACS Workstation, despite the fact that a PC monitor has intrinsically more noise and convergence error than does a workstation monitor, cannot display as many pixels as can the workstation monitor, and is only a little more than one third as bright [20]. Finally, the lack of certified requirements for medical display for referring physicians, emergency physicians, and orthopedic surgeons make the use of paper film valid from a medicolegal point of view.

It might be surprising that in our study the inter-reader agreement was substantial or almost perfect for all techniques, whereas the analysis of plain radiographs is sometimes very challenging, particularly for the diagnosis of

Table 3 Inter-technique agreement

Kappa values with 95 % confidence intervals	Reader 1	Reader 2
Laser film/PACS	0.99 (0.97–1.00)	0.90 (0.85–0.96)
Laser film/paper	0.89 (0.83–0.95)	0.86 (0.80–0.92)
PACS/paper	0.88 (0.82–0.95)	0.84 (0.78–0.91)

scaphoid fractures [4, 21]. In the Tiel-van Buul study, the interobserver agreement between experienced radiologists reading initial radiographs for the detection of scaphoid fractures was 0.76 [22]. In Ottenin et al., three readers read 100 consecutive wrist trauma cases on a PACS workstation, and the interobserver kappa value varied between 0.54 and 0.59 for the diagnosis of fractures on standard radiography. However, the study group was composed of patients who underwent tomosynthesis and CT scan because of inconclusive radiographs or a discrepancy between the clinical and the radiological data. This study group represented 4.5 % of the total number of patients, suggesting that in most cases, the diagnosis is usually straightforward on clinical and radiological data only [23]. It is probable that the frequency of the challenging cases in our study is similar to that of Ottenin et al.

The present study has certain limitations; the first being the absence of a reference examination such as a CT scan or an MRI examination of the wrist. However, the goal was not to define the accuracy of the technique, but to determine the reproducibility of the reading on different media in order to validate possible substitutions. Besides, it is not ethically possible to determine the accuracy of plain films in the general population as in the majority of cases, plain films are sufficient. The second limitation relates to the lack of anonymity of the cases. In practice, this information must be available for the radiologists as the prevalence of the lesions depends on the age and sex of the patients. This might lead to a memory effect and artificially increase the degree of agreement. However, the high number of examinations, the randomized reading, and the delay between the readings minimized this bias. Finally, as the type, grade, and displacement of the fractures were not analyzed in our study, further evaluations are required to determine the reproducibility in classifying the fractures with the different media.

Conclusion

Despite a lower spatial resolution and low-contrast resolution, with a layout of one radiograph on each sheet, paper could replace laser films to communicate the results of wrist radiographs in trauma cases.

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