

New Research on Colposcopy: Results of a Two-phase Study to Test Digital Colposcopy and Telecolposcopy in Clinical Practice

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Abstract

Objective: It is proposed that digital colposcopy and telecolposcopy should facilitate the medical decision-making process and raise the validity of the diagnosis of cervical carcinoma thereby lowering the incidence and mortality rate of the disease. In order to test this, a digital colposcopy system was developed and clinically evaluated within the framework of a two-phase scientific study at the Charité Dysplasia Clinic Berlin.

Materials and Methods: In Phase 1 of the evaluation, a total of 315 patients were examined with the digital colposcopy system consisting of a binocular colposcope supplemented with a colour camera and PC, to see whether colposcopic findings can be re-evaluated on the basis of the stored digital images alone, i.e. without the patient being present.

Phase 2 was used to test the technical feasibility and reliability of sending colposcopic images by electronic mail. A total of 30 patients from four selected gynecological practices in Berlin had been referred for diagnostic clarification to the Charité Dysplasia Clinic. The digital colposcopic images made there were sent as e-mails to the referring doctors, who in turn evaluated the data transfer.

Results: In Phase 1, the primary and secondary examiners were in total agreement in 69% of the cases ($\kappa=0.60$). No significant bias in terms of under- or over-rating was observed ($p<0.05$ by McNemar's test). In Phase 2, in 57% ($n=17$) of the cases, a lack of experience with the new technique led to difficulties with downloading the images. When the practices had become more familiar with the procedure, the incidence of problems fell from 90% (9/10), in the first half of the project, to 40% (8/20) in the second half. In 87% of the cases, the diagnosis of the consulting specialist at the Charité Dysplasia Clinic was comprehensible to the practising physicians.

Discussion: Digital colposcopy and telecolposcopy can be effectively used in colposcopy to compensate for the inherent disadvantages of the method, i.e. a high level of inter- and intra-observer variability, inadequate reproducibility and objectivity of colposcopic findings, data storage, data transmission. In practice, there are clear advantages for the diagnosis documentation, follow-up monitoring, further medical education, as well as interdisciplinary communication.

Keywords: cervical carcinoma, early diagnosis of cancer, digital colposcopy, telecolposcopy

Özet

Kolposkopide Yeni Araştırmalar: Klinik Uygulamada Dijital Kolposkopi ve Telekolposkopinin Değerlendirme Sonuçları (Faz 1-2)

Amaç: Dijital kolposkopi ve telekolposkopinin servikal kanser tanısının konmasını kolaylaştıracağı ve tıbbi karar sürecini değiştireceği ve bu şekilde bu hastalığın insidans ve mortalitesinde azalmaya yol açacağı hipotezi ortaya konuldu. Bu hipotezi test etmek için Berlin Charité Displazi Kliniği'nde bir dijital kolposkopi sistemi geliştirildi ve Faz 1-2'yi kapsayacak bir araştırma yapılması planlandı.

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Materyal ve Metot: Çalışmanın Faz 1 aşamasında 315 hasta dijital kolposkopi sistemi ile muayene edildi. Bu aşamada renkli bir kamera ile PC bağlantısı sağlanmış bir binoküler kolposkop yardımı ile hasta klinikte mevcut değilken kaydedilmiş dijital görüntülerden yola çıkarak, bir klinik değerlendirmenin mümkün olup olmadığı test edilmiştir. Faz 2 aşamasında kolposkopik görüntülerin elektronik posta aracılığı ile gönderiminin teknik olanakları ve güvenilirliği test edildi. Bu aşamada Berlin'de önceden belirlenmiş jinekoloji kliniklerinden 30 hastaya ait veri Charité Displazi Kliniği'ne konsültasyon amacıyla gönderildi. Burada oluşturulan dijital kolposkopik görüntüler tekrar refere eden hekime e-posta yoluyla gönderilerek veri transferi konusundaki değerlendirmeleri araştırıldı.

Sonuçlar: Faz 1'de verileri primer ve sekonder inceleyen araştırmacıların birbirleriyle uyumları %69 idi ($\kappa=0.60$). Verileri olduğundan daha az veya daha fazla önemli değerlendirme anlamında yan tutma (bias) gözlenmedi ($p<0.05$; McNemar's test). Faz 2'de vakaların %57'sinde ($n=17$) görüntülerin bilgisayara indirilmesi ile ilgili teknik tecrübe eksikliğinden dolayı sorun yaşandı. Yöntemin zaman içinde uygulayıcılar tarafından öğrenilmesi nedeniyle çalışmanın ilk yarısındaki %90'lık (9/10) sorun oranı, projenin ikinci yarısında %40'a (8/20) düştü. Vakaların %87'sinde Charité Displazi Kliniği'nde konsültan hekim tarafından konulan tanı vakayı gönderen klinisyenler tarafından uygun bulundu.

Tartışma: Dijital ve telekolposkopi, kolposkopinin uygulaması sırasında ortaya çıkan yüksek inter- ve intraobserver varyabilite, yetersiz tekrar edilebilirlik-yetersiz kolposkopik bulgu objektivitesi-yetersiz veri depolama ve yetersiz veri aktarımı gibi dezavantajları ortadan kaldıracaktır. Pratikte bu uygulama ile tanının belgelenmesi, takip muayenelerinde kolaylık, sürekli tıp eğitimi ve interdisipliner iletişim açısından belirgin avantajlar bulunmaktadır.

Anahtar sözcükler: servikal kanser, erken tanı, dijital kolposkopi, telekolposkopi

Introduction

About 20-40% of the services in health care are those involved with data collection and communication (1). In order to organize these processes as effectively as possible, medical data must be available in a digital form (2). The advantages of digitalization in an attempt to increase the reliability of diagnosis are obvious. Both the quality and access to the patient documentation are optimized (electronic patient record). Follow-ups during treatment are facilitated by an objective description of the diagnostic findings. The possibilities of training and further education for medical staff are enhanced (e-learning). Furthermore the quick and secure exchange of existing information and available knowledge between medical partners is supported (electronic referral letter, electronic prescription, second opinion).

In gynecology, there has been a period of intensive research activity since 2000, concerning the use of telecolposcopy (3-11), although the potential of archiving data from digital colposcopy had been investigated prior to this (12-20). Common screening programs used in the detection of early stages of cervical cancer can profit enormously from the new technology. Both digital and telecolposcopy are conducive to an improvement in the objectivity and reproducibility of the colposcopic findings, and therefore help in propagating the colposcopic method in clinics, doctors' practices and in the education of students and qualified doctors alike. The main aim is to supplement the established screening methods (screening cytology, Pap-test) with a highly effective method, and thereby further reduce the incidence and mortality of cervical cancer, not only in Germany but also in countries in and outside Europe.

This paper presents our own results from a research project carried out over a 5 year period (2000-2005) and verifies the advantages of the use of digital and telecolposcopy in gynecological practice.

Materials and Methods

Technical systems

A digital colposcopy system was developed consisting of a standard binocular colposcope (ZEP 505, M/s. Zeiss, Germany) supplemented with a CCD camera (MediLive, M/s. Zeiss, Germany) and a PC with a frame grabber card (LC1, M/s. DBS, Germany) with which colposcopic images can be stored during examination, either per mouse click or with a foot switch. The images can be stored in the usual data formats i.e. either bmp (required storage space per image: 1.7 MB) or jpeg (300-500 kB). The software (ColpoData, M/s. LMTB, Germany) makes up the core of the system. It was specially developed not only because it facilitates easy administration of all the relevant patient examination and

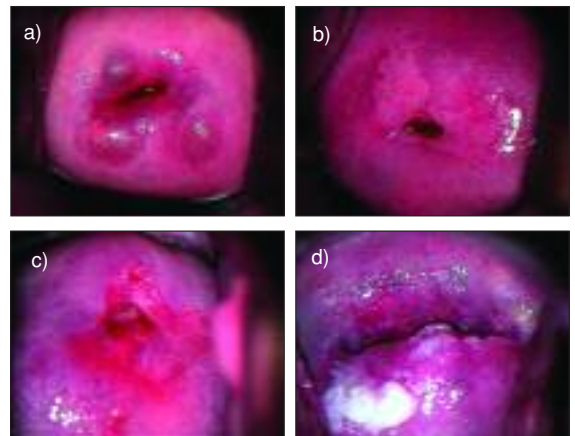


Figure 1. Rating of primary and secondary findings. Post-acetic images with magnification factor x5: a) normal (non-suspicious): Ovula Nabothii, b) slightly suspicious: minor acetowhite epithelium with minor mosaic, c) moderately suspicious: major acetowhite epithelium with major mosaic and punctation, d) strongly suspicious: thick leukoplakia.

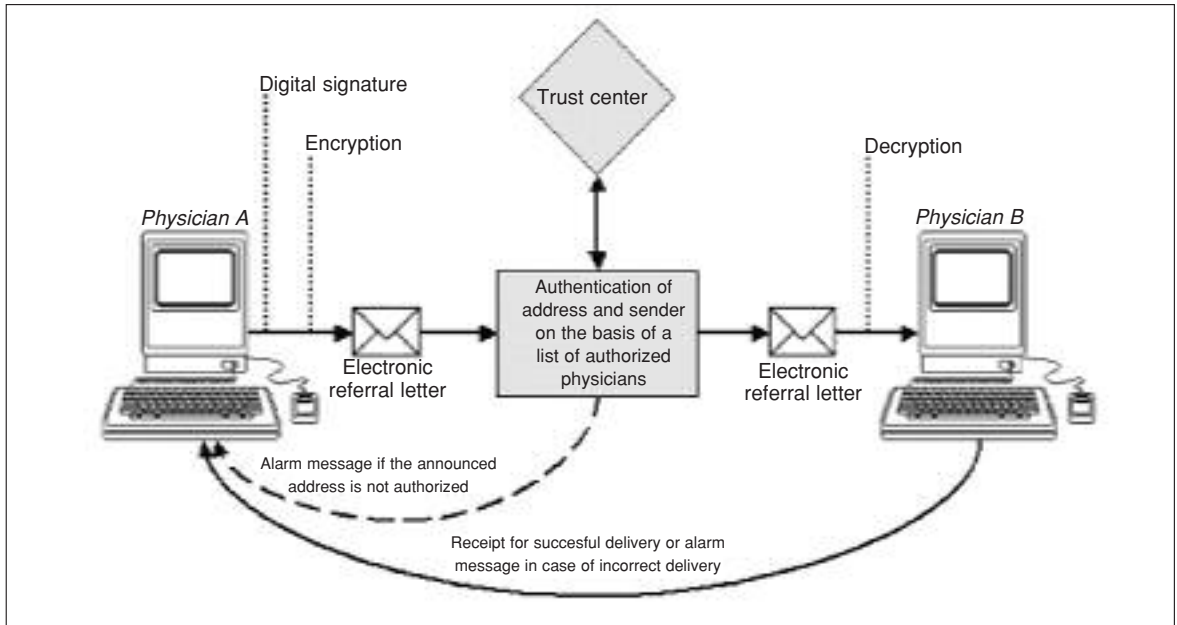


Figure 2. 'PaDok[®]'-communication network for the secure exchange of data

image data in the form of an electronic patient record (EPA), but also it allows semi-automatically formulated electronic referral letters (e-letter), into which the digital colposcopic images can be integrated, to be forwarded on.

System evaluation

The technical evaluation of the system took place in two phases.

In Phase 1 the question posed was whether the quality of the images captured were of sufficient quality for the colposcopic findings to be re-evaluated by a second physician on a PC, without the patient being present. For these investigations a clinical pilot study was carried out in co-operation with the Charité Dysplasia Clinic Berlin. A total of 315 patients were examined in the time period 2000-2003 using the digital colposcopy system. They had all been referred to the Charité Dysplasia Clinic by their doctors for further diagnosis due to cytological and/or colposcopic abnormalities on the portio. The colposcopic examination involved 1-2 images being captured at different colposcope magnifications for each functional test (native; acetic acid; Schiller's test with iodine) and which were then stored together with the colposcopic findings (defined as primary diagnosis). Afterwards, a re-evaluation (defined as secondary diagnosis) of the initial diagnostic findings was made on the basis of the stored digital images alone, i.e. in the absence of the patient, by a second doctor trained in colposcopy who had no knowledge of the primary colposcopist's diagnosis.

The primary findings, from the patient examination, and the secondary findings made on the PC, were categorized

according to the Rome-classification (21) into 4-stages of classification (normal, slightly suspicious, moderately suspicious, strongly suspicious) and compared with one another (Figure 1). In order to compensate for different levels of experience (inter-observer variability) each of the physicians taking part in the study acted as primary and secondary examiners for half of the patients respectively. McNemar's test and Cohen's Kappa statistic were used for statistical analysis of the results.

In Phase 2 of the system evaluation the technical feasibility and reliability of the electronic dispatch of colposcopic findings was investigated. High quality digital images taken by specialists at the Charité Dysplasia Clinic, used in Phase 1 to complete patient documentation, were sent to the patient's original doctor in the form of an e-letter. The aim was to get the maximum amount of information to the referral physician as quickly as possible in order to support further treatment. For this the digital colposcopy system was integrated into a medical 'doctor-to-doctor' data network (D2D, M/s. KV Nordrhein, Germany) as patient data cannot be sent by the usual e-mail programs for reasons of data protection in Germany. The communication within this network is based on the patient documentation safety concept 'PaDok[®]' of the Fraunhofer-Institute for Biomedical Technology (IBMT), St. Ingbert/Germany (Figure 2), which relies on a so-called 'Client Server Model'. Patient data (in this case medical e-letters with integrated digital colposcopic images) were transferred by the sender onto a PaDok[®]-Server, which functions as an electronic postal box and to which only authorized persons have access i.e. the clients of this service. The

encryption and decryption of the patient data takes place automatically and is not visible to the user. 'PaDok®' excludes external access to the software systems of the involved PCs so that all security requirements are fulfilled relating to the confidentiality, integrity, availability, authenticity, possibility of revision, and transparency of sensitive data.

Trials for the communication network took place in the years 2004-2005 within the framework of a prospective field study in the form of a co-operation between the Charité Dysplasia Clinic Berlin and four resident gynecological practices in Berlin. In order to facilitate the electronic transfer of data, the digital colposcopy system was fitted on the transmitter side (Charité Dysplasia Clinic) with an ISDN¹ connection. Additionally, on the receiver side (physicians' practices), a specially developed mail software (D2D-Mail, M/s. LMTB, Germany) was installed which like the 'ColpoData'-Software was coupled to an ISDN port to enable the downloading of e-letters from the PaDok®-Server. Access authorization had to be obtained from all the physicians taking part (both Charité Dysplasia Clinic and practices) by the regional operating trust centre of the PaDok®-Server (KV Nordrhein, Germany). This ensured that the e-letters could only be sent and received when sender and receiver had been authenticated, which also meant that each physician was only able to access the data of his/her own patients.

A total of 30 patients were selected exhibiting cytological and/or macroscopic or colposcopic abnormalities of the portio. They had all been examined using the digital colposcopy

system in the Charité Dysplasia Clinic as described before. Digital colposcopic images were stored and sent in the form of an e-letter to the original attending doctor. Every e-letter included an average of 1-2 images at different magnifications for each functional test. The e-letters were always mailed in parallel to the written referral letters (usually without colposcopic images) sent by post, which are mandatory for the resident gynecological practices.

After receipt of the e-letters, the physicians were asked to evaluate the data transmission on the basis of a standard questionnaire relating to the transmission time and transmission quality, the usability of the integrated digital colposcopic images to reproduce the specialist's diagnosis, the reliability of the data transmission and the ease of handling of the technique. The procedure, as described here, was approved by the ethics committee of the Charité and by the Information and Privacy Commissioner of Berlin.

Results

Clinical pilot study (Phase 1)

The results of Phase 1 of the system evaluation have already been reported in some detail (22-24). A total of 315 patients with externally found abnormalities of the portio were included in the pilot study. From these colposcopic data sets 9.2% (n=29) could not be analyzed. The median age of the remaining patients (n=286) was 39 years (mean 42, SD±12).

For these patients, a total of 1590 images were stored digitally (Table 1). The 63% (n=998) of them were taken as

¹ Integrated Service Digital Network (ISDN) is a digital telephone data service standard. An ISDN connection is an internet connection established through a special phone line installed by the phone company. ISDN connections are popular in Europe and provide a relatively low-cost option for rural users with otherwise terribly slow internet access speeds e.g. via a modem.

Colposcope magnification	Native		Acetic acid		Iodine test		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
x5 (Overview)	384		300		314		998	(63)
x9 (Detail)	29		385		46		460	(29)
x14 (Detail)	7		124		1		132	(8)
Total	420	(26)	809	(51)	361	(23)	1590	(100)

Colposcope magnification	All images stored n	Images per patient		Mean	(SD±)	Median
		Max	Min			
x5 (Overview)	998	9	1	3.5	(1.3)	3
x9 (Detail)	460	8	1	2.1	(1.1)	2
x14 (Detail)	132	5	1	1.7	(0.9)	1
Functional test						
Native	420	5	0	1.5	(0.8)	1
Acetic acid	809	8	0	2.8	(1.5)	3
Iodine test	361	4	0	1.3	(0.6)	1
Total	1590	13	3	5.5	(1.8)	5

Table 3. Secondary findings from examiner 'A' in comparison with the primary diagnosis (n=143)

Secondary diagnosis by physician 'A' (Re-evaluation on PC)	Primary diagnosis by physician 'B' (Binocular Colposcopy)				Total
	Normal (non-suspicious)	Slightly suspicious	Moderately suspicious	Strongly suspicious	
Normal (non-suspicious)	31	3			34 (24%)
Slightly suspicious	20	48	14		82 (57%)
Moderately suspicious		4	18	1	23 (16%)
Strongly suspicious			2	2	4 (3%)
Total	51 (36%)	55 (38%)	34 (24%)	3 (2%)	143 (100%)

Under-rating n=18/143 (13%), Agreement n=99/143 (69%), Over-rating n=26/143 (18%)

Table 4. Secondary findings from examiner 'B' in comparison with the primary diagnosis (n=143)

Secondary diagnosis by physician 'B' (Re-evaluation on PC)	Primary diagnosis by physician 'A' (Binocular Colposcopy)				Total
	Normal (non-suspicious)	Slightly suspicious	Moderately suspicious	Strongly suspicious	
Normal (non-suspicious)	19	13			32 (23%)
Slightly suspicious	7	66	6		79 (55%)
Moderately suspicious		13	7	3	23 (16%)
Strongly suspicious			4	5	9 (6%)
Total	26 (18%)	92 (64%)	17 (12%)	8 (6%)	143 (100%)

Under-rating n=22/143 (15%), Agreement n=97/143 (68%), Over-rating n=24/143 (17%)

Table 5. Findings from the dysplasia clinic compared to the external initial findings (reason for referral)

		Diagnostic findings from the Charité Dysplasia Clinic						Total					
		Colposcopy non-suspicious			Colposcopy suspicious								
External findings from referral doctor's		Pap II	Pap IIw	Pap IIID	Pap III	Pap IV a/b	Pap V	Pap II	Pap IIw	Pap IIID	Pap III	Pap IV a/b	Pap V
Colposcopy (Macroscopy) <u>non-suspicious</u>	Pap II												
	Pap IIw												
	Pap IIID	1						1		3			5
	Pap III												
	Pap IV a/b												
Colposcopy (Macroscopy) <u>suspicious</u>	Pap II							5		2			8
	Pap IIw									1			1
	Pap IIID	1		1				1		8		1	12
	Pap III											1	1
	Pap IV a/b											3	3
Pap V													
Total		3		1				7		14		5	30

Cytological findings based on the Second Munich Cytological Classification (Pap IIw=repeat cytology)
 Pap IIID suspicious for CIN I=LSIL (low grade squamous intraepithelial lesion) based on Bethesda System Terminology
 Pap IIID suspicious for CIN II and Pap IVa=HSIL (high grade squamous intraepithelial lesion) based on Bethesda System Terminology

overviews at the smallest magnification (x5) available to show the cervix in its entirety. With respect to the colposcopic procedure, the majority of images (n=809; 51%) were acquired after swabbing with diluted acetic acid because of their particular relevance to the diagnosis, whereas further detailed images were made of suspicious lesions (x9; x14). Altogether a total of 3-13 images per patient (median: 5 images) were stored and assessed (Table 2).

According to the impressions documented by the primary examiners, a total of 73% (n=209) of the patients examined had colposcopic findings which were suspicious, of which 51% (n=147) of the cases were slightly suspicious, 18% (n=51) were moderately suspicious and 4% (n=11) were classified as strongly suspicious. This correlated well with the cytological and histological results found during colposcopic examination (23).

There was agreement between primary and secondary evaluation of the findings in 68.5% of the cases examined ($\kappa=0.60\pm 0.03$; 95% CI). Of those cases which did not agree, 14% were underrated and 17.5% were overrated by the secondary examiner whereby the rating differed by one classification level at the most.

In terms of the grade of agreement, both physicians reached qualitatively comparable results (Table 3, Table 4). For the physician 'A' as secondary examiner (Table 3) showed a slight trend to over-rating. However this can be ascribed to the significantly higher proportion of non-suspicious findings in the patient group concerned (n=51, 36% in Table 3 vs. n=26, 18% of physician 'B' in Table 4). Overall, McNemar's test showed no statistically significant bias to under- or over-rating by the secondary examiner compared to the primary examiner ($p<0.05$).

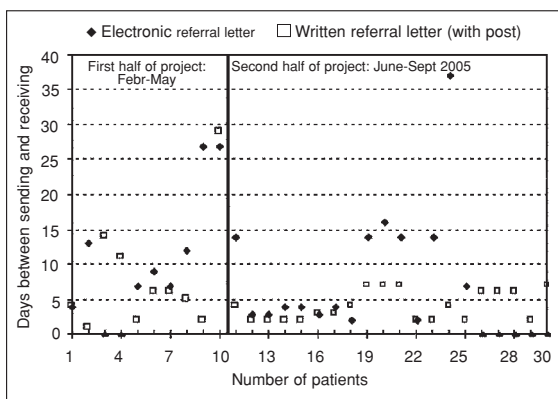
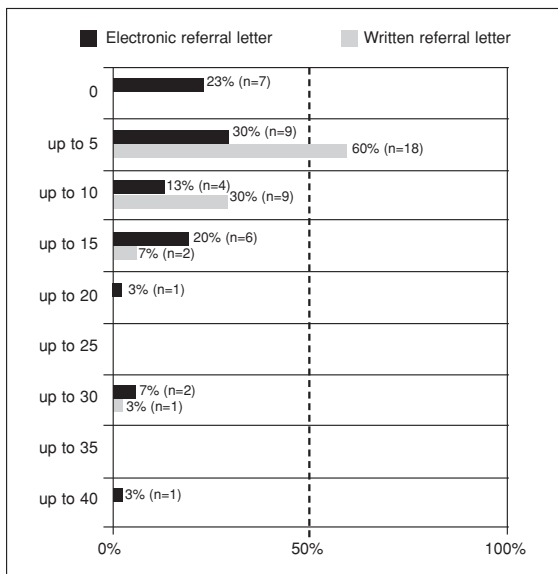


Figure 3. Length of time between dispatch and receipt of letters (letters with post vs. e-letters, n=30)

Based on the binocular colposcopy (primary findings), the digital colposcopy yielded a sensitivity of 92% (193/209) and a specificity of 64.9% (50/77). Comparison with histological results, the gold standard, was not possible as it was, and remains, non-ethically justifiable to the patient to take unnecessary biopsy material from the portio.

Prospective field study (Phase 2)

A total of 30 patients were selected for the field study, with a median age of 36 years (mean 39, SD±15). At the time of the examination the oldest patient was 77, and the youngest was 21-years-old.

The patients had been referred by their gynecologists for clarification to the Charité Dysplasia Clinic in Berlin, 16% (n=5) of them because of a suspicious Pap smear; 27% (n=8) because of macroscopic/colposcopic conspicuousness on the cervix uteri and 57% (n=17) because of conspicuous findings both of a colposcopic and cytological nature. Table 5 shows the results of patients' examinations at the Charité Dysplasia Clinic compared to the initial findings of the external doctors. It can be seen that 67% of the patients (20/30) showed a suspicious Pap smear and 95% (19/20) of them were also colposcopically suspicious. Of the 10 cytologically normal patients, 70% (7/10) had a macroscopically or colposcopically suspicious portio.

All study patients were subjected to a colposcopic examination using the digital colposcopy system in the Dysplasia Clinic. Per patient 1-9 images (median: 6 images) were taken at different colposcope magnifications (Table 7). A total of 173 images, mostly as an overview (n=93, 54%) and after swabbing with diluted acetic acid (n=94, 54%) were stored digitally (Table 6), embedded in the corresponding e-letters and, parallel to the required written referral letters containing no images, sent per e-mail to the transferring physicians.

It took on average 5.3 days (SD±5.4) between sending and receiving the written referral letters by post. The time taken between sending and downloading the e-letters was, on average, 8.2 days (SD±9.2) which was, against all expectations, 3 days longer than letters sent by post. Of the written referral letters 60% (n=18) reached their destination within 5 days of being sent whereas for the e-letters it was 53% (n=16). However 23% (n=7) of them were 'picked up' from the PaDok® -Server on the same day as they were electronically sent (Figure 3, left). More delays occurred, particularly at the beginning of the field study, whilst downloading the e-letters (Figure 3, right). Considering the entire project duration, according to information given by the participating physicians' practices, problem free downloading was possible in 43.3% of the cases (n=13). Technical problems occurred with 17 e-letters (56.7%), 41.2% (7/17) of them being downloaded later (e.g. interruption of the client server connection) and 58.8% (10/17) with help of the technical support.

In addition to the technical reliability, the participating physicians were asked to evaluate the quality of the

Table 6. Number of stored digital images per colposcopic functional test (n=173) used for integration in the e-letters in Phase 2

Colposcope magnification	Native		Acetic acid		Iodine test		Total	
	n	(%)	n	(%)	n	(%)	n	(%)
x5 (Overview)	30		32		31		93	(54)
x9 (Detail)	8		43		7		58	(34)
x14 (Detail)	2		19		1		22	(13)
Total	40	(23)	94	(54)	39	(23)	173	(100)

Table 7. Number of digital images per patient and e-letter (n=30) in Phase 2

Colposcope magnification	All images stored		Images per patient				
	n		Max	Min	Mean	(SD±)	Median
x5 (Overview)	93		6	1	3.1	(1.1)	3
x9 (Detail)	58		4	0	1.9	(1.1)	2
x14 (Detail)	22		4	0	0.7	(1.0)	0
Functional test							
Native	40		4	0	1.3	(0.8)	1
Acetic acid	94		5	0	3.1	(1.3)	3
Iodine test	39		2	0	1.3	(0.5)	1
Total	173		9	1	5.8	(1.6)	6

e-letters. The overall quality of the e-letters was mainly rated as 'good' (n=14, 47%) and 'excellent' (n=14, 47%) with only 2 e-letters being rated as 'acceptable', and none as 'unacceptable'.

The image definition was also rated as 'good' (n=13, 43%) and 'excellent' (n=14, 47%). For 3 (10%) of the e-letters the image quality was classified to be only 'acceptable'. The image magnification of the integrated digital images was also from the physician's point of view and in 97% (n=29) of the cases, sufficiently detailed to identify colposcopic abnormalities. Using these images it was possible in 87% (n=26) of the cases to follow the diagnosis of the specialist from the Charité Dysplasia Clinic without any problem.

Discussion

With the introduction of quality management systems in medicine, there are increased requirements with regard to the quality of the physician's diagnosis. This is closely linked to an efficient and objective documentation of medical diagnostic findings, which can only be achieved with help of modern data processing and communication technologies.

The establishment of digital and telecolposcopy systems could aid the spread of the know-how involved for the colposcopic method, as colposcopic findings can be made independent of place and time, and can be forwarded and re-evaluated i.e. by specialists.

From the technical point of view, such a system must fulfil set minimum requirements relating to capturing, replay and transmission quality of digital colposcopic findings in order to allow them to be used for documentation and telemedical

applications (e.g. 'second opinion', electronic referral letter) in medical practice. The results of the two-phase study presented here justify the conclusion that the digital colposcopy system developed comes up to these technical standards.

Clinical pilot study (Phase 1)

The quality of the digital images (resolution, brightness and contrast, colour fastness) is determined primarily by the choice of a suitable camera system. The camera used here was a standard binocular colposcope adapted 1/2 inch camera (M/s. Zeiss, Germany) which gave images with a resolution of 752x582 pixels. The quality was good enough to reproduce the colposcopic findings for a second opinion. The agreement between the two physicians involved in Phase 1, acting alternately as primary and secondary examiner, was 69%. The basis for comparison of the observed colposcopic abnormalities was a four step classification scheme (normal, slightly suspicious, moderately suspicious, strongly suspicious) as is described in detail in a former article from us (23). This differentiated rating justified the difference between the comparatively low value of $\kappa=0.6$ (moderate agreement) we had calculated and the result of $\kappa=0.7$ (strong agreement) in a similar study (9), in which video sequences were assessed by a second opinion and a differentiation was only made between 'normal' and 'suspicious'. It is obvious that a detailed classification model to assess the findings will reduce the level of consensus between primary and secondary examiner.

If we were to recalculate the level of agreement using also only two classes ('normal' vs. 'suspicious') the level of agreement would rise to 85% and by including adjacent categories ('normal/slightly suspicious findings' without a

therapeutic consequence versus 'moderately suspicious/strongly suspicious' with therapeutic relevance) would even rise to 87%.

Independent from the classification model used, the image definition, choice of the display detail and magnification of the stored digital colposcopic images are all essential for re-evaluation on the PC. These parameters, in addition to the camera technique, are largely determined by the technical know-how and experience of the primary examiner using digital colposcopy.

The system developed by us is characterized by its simple handling. The technical know-how is easily learnt, which is reflected in the relatively low percentage (9%) of non-evaluable images compared to those values, 14% and 23%, found in the literature (14,18). The most common causes for insufficient image quality, especially at the beginning of the study, were difficulties with adjustment of the speculum to display the portio and problems with co-ordination of the focus between binocular and video camera. Commercial colposcopic systems are now available on the market with completely integrated camera technology, which combines improved handling (e.g. single handed operation) with outstanding optical quality.

However, for good reproducibility of the colposcopic findings using the digital images, a suspect lesion of the portio or the cervix uteri should be shown in detail using different colposcopic magnification levels, as we did during the clinical pilot study (Phase 1).

A total of 1590 digital images were stored in the first phase of the system evaluation for the 286 evaluated patients (see Table 1) of which about 2/3 (63%) were images providing an overview i.e. with the smallest magnification, and about half (51%) were taken after swabbing with diluted acetic acid. These values are in good agreement with the recommended procedure we usually used in Phase 1 where an overview image was taken, ideally, after every function test (native, acetic acid, iodine test) for each patient examined and further images were only taken at higher magnification if conspicuous details appeared after the acetic acid test. Given a median of 5 stored images per patient (see Table 2), 60% i.e. 3/5 of the images would be expected at the lowest magnification and 60% i.e. 3/5 after the acetic acid test. The image quality achieved (Table 1) agrees well with these figures, particularly when one considers that for colposcopically normal patients (77/286=27%, see Table 3 and Table 4) only an average of 3 images were made.

It should also be pointed out, that a commercially available 17 inch PC monitor, such as we used in Phase 1, was sufficient for the replay of the digital images for the second opinion. No special technical requirements were necessary which contrasts dramatically with the strict guidelines given for monitors used in teleradiological diagnostic procedures.

All in all, it could be shown that the recording and replay quality attained with the digital colposcopic system was good enough to reproduce the findings on the PC with a sensitivity of 92% and a specificity of 65%, without the patient having to be present. No significant over- or under-rating of the findings by the second examiner was found. McNemar's test resulted in no method dependent bias. This meant that the most important conditions were established to use the developed colposcopy system in telematics (e.g. to obtain a second opinion). The following field study was therefore concerned with investigation of the technical feasibility and reliability of the electronic transfer of colposcopic findings.

Prospective field study (Phase 2)

The set-up of a secure communication network between the participating partners (Charité Dysplasia Clinic Berlin, gynecological practices) was made easier by two important aspects. Firstly, it was possible to make use of an existing communication concept which had already been tested by various medical authorities (PaDok®, M/s. IBMT St. Ingbert, Germany) and which fulfilled data protection guidelines with regard to coded transmittance of sensitive patient data (25-28).

Secondly, the electronic transmission of digital colposcopic images, which had been captured with the digital colposcopic system, required no specific transmission technology for the size of the data files used. This is in sharp contrast to the DICOM format used in teleradiology which has data files of several hundred megabyte needing so-called 'virtual private networks' (VPN) with high bandwidth/data rate for data transmission. An electronic referral letter with integrated digital colposcopic images can be transmitted using a normal ISDN connection. The download time required per e-letter took a workable time of 10-30 minutes, depending on the number of integrated digital images in JPEG format (data size: 1.8-3 MB). It would be possible to considerably speed up the transmission also using VPN. However the cost of the required provider services is higher than those for conventional ISDN connections which as a rule, physicians' practices usually have, making an additional technical upgrading unnecessary. With regard to data protection, there is no difference between the types of transmission channels (ISDN, VPN) as they both are based on the 'PaDok®' security system.

Concerning the technical reliability of the communication network selected by us, according to information given by the gynecological practices, a trouble-free reception of the e-letters was only possible in 43% (13/30) of the cases. The main reason for this, in addition to technical hitches, was unfamiliarity with the software required to download the e-letters (D2D-Mail, M/s. LMTB, Germany). A 'learning by doing' effect could be observed when the technique was used more frequently. The problems experienced when downloading the e-letters sank significantly from 90% in the first project half (February-May 2005) to 40% in the second project half (July-September 2005). This shows the importance of sufficient user schooling as well as personal support

during the introductory phase of telematic applications. The use of a new computer program requires more time and organization, thereby preventing the integration of the new technique into everyday practice. This was reflected by the fact that, contrary to expectation, the e-letters took 3 days longer to reach their addressees (see Figure 3). The user-friendliness could be further optimized by further simplification of the needed software together with a direct integration of the digital images into an electronic patient record.

Independent of the technique used to send the e-letters, the principle transmission quality of the electronic referral letters was unanimously rated as 'excellent' by all of the doctors taking part in the field study. The total quality of the letters was 94% and the definition of the integrated images was 90% giving of rates 'excellent' and 'good' respectively. This result is echoed in the comparison of the quality of the acquired images from Phase 1 (see Table 1, Table 2) and Phase 2 (see Table 6, Table 7) of the system evaluation. During the field study doctors were sent e-letters with qualitatively equivalent images to those they were used for re-evaluation on PC in Phase 1.

There are distinct advantages for further treatment compared to the usual written referral letters without colposcopic images namely:

- Better monitoring of the diagnosis by using PC images (quality management) and therefore additional safety for doctors who do not use colposcopy very often.
- Improved follow-up as initial findings, particularly from different examiners, can be compared with one another more easily on the basis of digital images.
- Simplification of further stages in the therapy planning by confirmation of the diagnosis by a specialist (thereby avoiding over-treatment such as conization).
- Improved quality of the colposcopic method.
- Improved involvement of the patients in the therapy process, individually increasing the feeling of responsibility for themselves.

Altogether the data transmission was shown to be stable and technically feasible.

Summary

The development of a digital colposcopy system with telematic utilization options is a contribution to the goal to raise the diagnosis reliability of colposcopy and to optimize the transmission of colposcopic findings with regard to recording quality as well as rapid accessibility and exchangeability.

Colposcopy, as a supplement to cytology, constitutes an important method for the detection of early forms of cervical cancer. Using the results of this two-phase study it could be shown that the efficiency of the colposcopic examination could be further increased by use of the digital colposcopy system. An improvement in the diagnosis will result from

an optimization of patient documentation (digitalization of data findings by means of electronic patient records) and the promotion of communication between the medical partners by use of telematic options (support by telephone consultations or remote diagnosis, obtaining second opinions). In order to reduce the throughput time of transmitted diagnostic findings, the hard- and software used for the transmission of electronic referral letters must not only be technically reliable but also user-friendly. The undisputed advantages for using digital technology are an improvement in the participating physicians' own further training (training effect, operator control), an improvement in the public image of the medical authorities (special service: e-letter) and a more active patient involvement in the course of the treatment.

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