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Is image selection a useful strategy to decrease the transmission time in teleradiology? A study using 100 emergency cranial CTs

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Abstract. This study examines the suitability of working with a selection of images in a teleradiology consulting system in neurological or neurosurgical emergency situations. The teleradiology system was based on IBM-compatible personal computers, video digitization for data acquisition, and data transmission by Integrated System Digital Network. Forty normal and 60 abnormal emergency cranial computed tomograms were shown to a radiologist on call who presented all cases he regarded as pathologic to a neuroradiologic expert by teleradiology. To reduce transmission time, only a selection of images from the CT study was presented (up to four images per case). For each case the on-call radiologist's diagnosis ($D_{on\text{-}call}$), the expert's diagnosis on the teleradiology screen ($D_{monitor}$), and the expert's diagnosis on the original film ($D_{original}$) was documented, together with an estimation of the agreement between those diagnoses. There was clinically relevant disagreement between the on-call radiologist's diagnosis and the neuroradiologist's diagnosis based on the image selection on the teleradiology monitor in 23 % of cases. A clinically important discrepancy between the neuroradiologist's diagnosis based on the image selection and his diagnosis using the original films was found in 30 % of cases. This was due to the presence of clinically relevant information on images not transferred by the on-call radiologist. Image quality of the transferred images was sufficient in all cases. Drastic selection of images from a complete CT study leads to a high rate of incorrect diagnoses and is not appropriate to reduce transmission time in teleradiology.

Key words: Teleradiology – Telemedicine – ISDN – Image selection

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Introduction

According to ongoing technical development there is a growing number of reports about teleradiology systems of very different technical performance and different purchasing and running costs [1–7]. The most important technical differences concern the way of image data acquisition, the hardware requirements, and the mode and speed of data transfer.

The more sophisticated teleradiology systems use the DICOM standard for primary digital data acquisition from CT scanners, are frequently based on UNIX workstations, and use ATM channels or an array of Integrated System Digital Network (ISDN) lines [8, 9] for telecommunication. Less sophisticated teleradiology systems often use analog image data acquisition through a scanner or video system, are based on widespread hardware systems, such as IBM-compatible personal computers, and transfer data by solitary two-channel ISDN connections.

One of the major indications for teleradiology is the transfer of computed tomograms in neurologic or neurosurgical emergencies, in which teleradiology can improve patient care and reduce costs by avoiding unnecessary patient transfers [10]. A critical point in many low-cost systems used in this emergency setting is the long data transfer time [11]. We examined the suitability of severe image selection in teleradiology by simulating an emergency situation in which an experienced radiologist on call had the opportunity to present those to a neuroradiological expert. The study was designed to answer the following question: Is severe image selection a useful way to decrease transmission time?

Materials and methods

The teleradiology system is based on a software package by DIP (Wuppertal, Germany) for IBM-compatible personal computers (in this case 486 processing unit, 500-MB hard disc drive, 17" color monitor). Input device is

Table 1. Pathologic findings in the selected cranial CT studies

Finding	*N*
No pathological findings	40
Hemorrhage	21
Infarction	15
Tumor	4
Others	20

Table 2. Scaling system for the agreement between different diagnoses

Agreement	Description
Excellent	No discrepancy at all
Good	Discrepancy in a minor, clinically irrelevant aspect
Partial	Discrepancy in one clinically relevant aspect
Poor	Discrepancy in more than one clinically relevant aspect
None	No agreement at all

a zoomable video lens connected to an analog/digital processor (8 bit). Data transfer is done by a two-channel ISDN connection with a data transfer rate of 64 Kbit/s per channel. The 100 emergency cranial computed tomograms (CCT) used in this study came from routine examinations done between August and October 1994. From this period of time 40 studies reported as normal and 60 reported as abnormal were taken in chronologic order, respectively (Table 1). Forty normal and 60 abnormal emergency cranial CCTs were selected chronologically between August and October 1994 (Table 1). The average number of images per CCT study was 27 (range 18–44 images). All 100 CCT studies were shown to one of the on-call radiologists. All cases found to be abnormal by the on-call radiologist were presented to an experienced neuroradiologist by the teleradiology system. The CT films had to be scanned individually image by image by the on-call radiologist to provide the highest possible contrast and resolution. The on-call radiologist was allowed to transfer up to four images per case together with a short written diagnosis. There was no further interaction between the radiologist on call and the neuroradiologist. Computed tomography scans observed to be normal by the on-call radiologist were not transmitted.

The neuroradiologist made a diagnosis based on the selection of images he saw on the teleradiology monitor ($D_{monitor}$). For each case he estimated the agreement between his own diagnosis on the monitor ($D_{monitor}$) and the diagnosis of the radiologist on call ($D_{on\text{-}call}$) using a five-point scale (Table 2). Afterwards, the neuroradiologic expert viewed the complete original CT films and assessed the agreement between his own diagnosis based on the original film ($D_{original}$) and his former diagnosis with the image selection on the teleradiology monitor ($D_{monitor}$), using the same five-point scale.

Table 3. Agreement between the on-call radiologist's diagnosis ($D_{on\text{-}call}$), the neuroradiologist's diagnosis based on the selected images transferred by teleradiology ($D_{monitor}$), and the neuroradiologist's diagnosis based on the complete original CT films ($D_{original}$; percent of cases, $n = 61$)

	Agreement between $D_{on\text{-}call}$ and $D_{monitor}$	Agreement between $D_{monitor}$ and $D_{original}$
Excellent	52	38
Good	25	33
Partial	20	21
Poor	3	7
None	0	2

Results

Sixty-one of the 100 CT scans were considered abnormal by the on-call radiologist, and 39 were assessed as normal. An average of 2.7 images per case were transferred. Average time for digitization and transmission was approximately 3 min, digitization and transmission taking equal amounts of time, respectively. The figures for the agreement between $D_{on\text{-}call}$, $D_{monitor}$, and $D_{original}$ are listed in Table 3. The discrepancy between two diagnoses was labeled "clinically relevant" if it was "partial" or "poor". According to this definition, there was a clinically relevant difference between $D_{on\text{-}call}$ and $D_{monitor}$ in 23 % of cases. A clinically relevant difference between $D_{monitor}$ and $D_{original}$ was found in 30 % of cases. In all cases of a clinically relevant discrepancy between $D_{monitor}$ and $D_{original}$ this was due to a failure to transmit clinically important images, either because the complete pathology could not be presented in four images or because pathological findings were missed by the on-call radiologist and therefore not transferred. In none of the cases image quality was responsible for a diagnostic discrepancy.

Discussion

The use of teleradiology in neurologic or neurosurgical emergency settings requires a sufficient image quality and a short digitization and transmission time. One possibility to reduce digitization and transmission time in a teleradiology-system is to transfer a small number of selected images only instead of the whole CT study.

Our study shows the effect of a drastic image selection (four images per case) by a radiologist on call, who presents this selection to a distant neuroradiologic expert by teleradiology: The drastic image selection leads to a high rate of diagnostic errors by the latter (clinically relevant discrepancy between $D_{monitor}$ and $D_{original}$ in 30 % of cases) because of clinically relevant information on images not transmitted. This makes the use of a drastic selection in the number of images not a suitable method to decrease transmission and digitization time. An image selection with more than four images transferred would probably lead to a lower rate of discrepancy between the neuroradiologist's diagnosis based on the selected images and on the complete films. But even with an image selection that is not so drastic, clinically relevant information could be lost due to the selection process. Other methods to reduce the time needed for image transfer, such as primary digital input, data compression algorithms, or the use of more than one ISDN channel, seem to be essential for the use of teleradiology in neurologic or neurosurgical emergency situations.

References

1. Batnitzky S, Rosenthal SJ, Siegel EL, Wetzel LH, Murphey MD Cox GG, McMillan JH, Templeton AW, Dwyer SJ (1990) Teleradiology: an assessment. Radiology 177: 11–7
2. Baxter KG, Wetzel LH, Murphey MD, Rosenthal SJ, Haines JE, Batnitzky S, Caresio JF, Templeton AW, Dwyer SJ (1991) Wide area networks for teleradiology. J Digit Imaging 4: 51–59
3. Dwyer SJ, Templeton AW, Batnitzky S (1991) Teleradiology: costs of hardware and communications. Am J Roentgenol 156: 1279–1282
4. Yamamoto LG, DiMauro R, Long DC (1993) Personal computer teleradiology comparing image quality of lateral cervical spine radiographs with conventional teleradiology. Am J Emerg Med 11: 384–389
5. Stewart BK, Lou SL, Wong WK, Huang HK (1991) An ultrafast network for communication of radiologic images. Am J Roentgenol 156: 835–839
6. Goldberg MA, Rosenthal DI, Chew FS, Blickman JG, Miller SW, Mueller PR (1993) New high-resolution teleradiology system: prospective study of diagnostic accuracy in 685 transmitted clinical cases. Radiology 186: 429–434
7. DeCorato DR, Kagetsu NJ, Ablow RC (1995) Off-hours interpretation of radiologic images of patients admitted to the emergency department: efficacy of teleradiology. Am J Roentgenol 165: 1293–1296
8. Engelmann U, Schröter A, Baur U, Schroeder A, Werner O, Wolsiffer K, Baur HJ, Göransson B, Borälv E, Meinzer HP (1996) Teleradiology System Medicus. In: Lemke HU, Vannier MW, Inamura K, Farman AG (eds) Computer Assisted Radiology 1996. Proc Int Symp on Computer and Communication Systems, Elsevier, Amsterdam
9. Sund T (1993) MIRA: teleradiology and digital radiology. Telektronikk 89: 33–36
10. Stoeger A, Strohmayr W, Giacomuzzi SM, Dessl A, Buchberger W, Jaschke W (1997) A cost analysis of an emergency computerized tomography teleradiology system. J Telemed Telecare 3: 35–39
11. Reponen J, Lahde S, Tervonen O, Ilkko E, Rissanen T, Suramo I (1995) Low-cost digital teleradiology. Eur J Radiol 19: 226–231

Book review

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ESNR CD-ROM educational series, Lasion Europe N. V., Aartselaar, Belgium.
Balériaux D. et al: MRI of Spinal Cord Diseases, vol. 1, **US $ 195.00, Edition ’95–’96.**
Patay Z. et al: Applied MR Neuro-Angiography, vol. 2, **US $ 195.00, 1997.**
Wilms G. et al: Imaging of Cerebral Tumors, vol. 3, **US $ 195.00, Edition ’97–’98.**

(continued from p. 1718)

2. *Applied MR angiography.*
By Z. Patay et al.
MR angiography has become a very important modality in neuroradiological examination. The quality of the images has become increasingly good and MRA can compete with more invasive procedures for a wide range of indications: cortical artery stenosis, abnormalities of the circle of Willis diagnosis, control of arterio-venous malformations after therapy, diagnosis of aneurysms and even screening, where indicated.

This CD-ROM shows a tremendous collection of MR angiographies of more common and rare cerebrovascular disorders. Of course, this demonstration is preceded by a technical explanation of how MR angiography for the head and neck vessels should be performed. This is the part that also shows the weakness of the CD-ROM concept. Technical developments follow each other so rapidly that within 1 or 2 years new techniques are available which are faster, with less artefacts and higher resolution. The same is, of course, true for books and even of articles.

3. *Imaging of cerebral tumours.*
By G. Wilms et al.
As in the other two CD-ROMs, an impressive collection of pathology has been brought together to produce a unique teaching file and reference text. In this CD-ROM, both CT and MR images are used, often giving additional information. Together with the CT and MR images, histological findings and gross pathology of brain tumours are illustrated, and are easily produced by double clicking. Images are again of high quality and the usual postprocessing functions are available.

Price/contents: Each of the CD-ROMs is priced at US $ 195. This is approximately the price that each of the volumes would have cost in book format, or perhaps a little more.

In this case, however, one has the added bonus of making acquaintance with a new medium in teaching and learning radiology. One can expect that on CD-ROM and via the Internet, more and more possibilities for electronic teaching and referencing will become available. This is a good introduction to those possibilities.

The three authors have to be complimented on their achievement.

J. Valk, Amsterdam