



Telemedicine for cardiac surgery candidates

R.F. Bonvini^a, L. Caoduro^a, A. Menafoglio^a, L. Calanca^a, L. von Segesser^b, A. Gallino^{a,*}

^aDivision of Cardiology, Ospedale San Giovanni, CH-6500 Bellinzona, Switzerland

^bDepartment of Cardiac Surgery, University Hospital, Lausanne, Switzerland

Received 13 February 2002; received in revised form 29 May 2002; accepted 6 June 2002

Abstract

Background: Cardiac surgery is generally well or over-represented in many Western countries. Since the southern part of Switzerland relies on 300 km distance centers for cardiac surgery, we started a project of telemedicine for the distant evaluation of cardiac surgery candidates. We report our experience of the results of the diagnosis made by telemedicine and by direct scrutiny of coronary angiograms. **Methods:** Coronary angiography was performed at the distant hospital by an invasive cardiology team. Teletransmission of images was performed using three Integrated Service Digital Network (ISDN) lines by direct transmission of recent recording. A total of 98 cases were reviewed (87 aorto-coronary bypass candidates, seven valvular and four congenital heart disease). We further performed a prospective blinded comparison of 47 consecutive cases with severe coronary artery disease (CAD) with respect to localization and number of significant coronary lesions, obtained by direct scrutiny of the original angiograms and the evaluation obtained with the teletransmitted images. **Results:** In 89 cases of the 98 analyzed (91%) correct diagnosis and surgical approach could be established by distant transmission. In nine cases (9%, all aortocoronary bypass candidates) definitive diagnosis and treatment was feasible only by direct scrutiny of the original angiograms. Five critically ill patients were urgently referred to the surgical care center based on the correct distant diagnosis. The blinded comparison of distant diagnosis and direct scrutiny of angiograms in defining 1-2-3 vessel CAD was good: $r = 0.87$, $P < 0.01$. **Conclusion:** Initial experience using non-sophisticated telemedical transmission of angiograms of cardiac surgery candidates seems to be a promising facility for distantly located centers. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Coronary angiogram; Telemedicine; Integrated Service Digital Network (ISDN) line; Cardiac surgery

1. Introduction

Telemedicine is the use of telecommunication and electronic information to provide medical services to sites at a distance from the provider. The application of telemedicine is in rapid expansion in different domains of medicine [1,2].

Based on the positive experience of years where doctors communicated with their patients when needed only by the support of the telephone [3], and made some decisions with a distant specialist, for the best care of their patients with the same technique, the development of more sophisticated technology, made the ‘birth’ of the telemedicine possible, especially in rural zones where specialist knowledge is missing, and distance often creates a logistic problem for the best and rapid treatment of a patient [1,2,4,5].

Telemedicine brings medical services where and when needed, especially from distant sites where specialists are lacking, to tertiary care centers [1,2,6,7]. Real-time facilities (i.e. interactive video) have the disadvantage of some loss of

the image quality, whereas asynchronously store-and-forward systems allow a complete transmission of data, albeit with significant long transmission times. The ‘in real time’ technique is preferable when an interactive immediate decision is required, whereas asynchronous transmission is best when the quality of the images is of major concern [2,8,9].

In the field of telecommunication there has been in the last years substantial improvement such as the application of the Integrated Service Digital Network (ISDN) that allows better, faster and cheaper medical images. This modern technique makes the use of telemedicine easier, more accessible in every medical field, and especially of good quality [8,10,11].

Based on our positive 5-year experience with on-line telemedical transmission of dynamic echocardiograms in pediatric cardiology at our primary care center [7], and because at the time of the study there was not a cardiac surgery support in the southern part of Switzerland, we started in 1997 a project on teleconsulting and teletransmission of invasive examinations (i.e. coronary angiograms) of

* Corresponding author. Tel.: +41-91-820-9107; fax: +41-91-820-9169.

E-mail address: agallino@bluewin.ch (A. Gallino).

cardiac surgery candidates with the heart surgery department of a tertiary university center (CHUV Lausanne).

2. Methods

We analyzed retrospectively the results of our initial experience in 98 cases (87 coronary-coronary bypass candidates, seven with valvular and four with congenital heart disease) with respect to distant correct diagnosis, surgical approach, direct teleconsulting between local cardiologist/patient and distant cardiac surgeon, as well as an urgent referral based on the distant diagnosis. The time period during which distant cardiac surgery consultations were performed was January 1998 through October 1998.

Teletransmission of the images was performed using three ISDN lines (corresponding to six channels transmitting 64 kbit/s each) and utilizing the video facility of an Acuson Sequoia C256 for direct transmission of the recent coronary angiograms. Coronary angiograms were taped on super-VHS cassettes. For the image transmission, the videotape exit was connected to the teleconference system (GPT Focus 400) with a standard of transmission of H320. For selected cases where heart surgeons were not able to establish distant diagnosis, an upgrading to a 4-ISDN transmission was temporarily established.

We further performed a prospective blinded comparison of 47 consecutive cases with severe coronary artery disease (CAD) with respect to localization, number of significant coronary lesions, and left ventricular global and segmental function, obtained by direct scrutiny of the original coronary angiograms and the evaluation obtained by the teletransmitted coronary angiograms.

The teletransmitted coronary angiograms and the original films were blindly evaluated and documented by the distant located heart surgeon at the tertiary care center and the invasive cardiologist at the primary site, respectively. The results of these independent evaluations were then compared, for quality evaluation of the teletransmitted images.

The parameters analyzed and considered for our analysis were the severity of the coronary artery disease according to the presence of 1-2-3 vessel disease, the numbers of significant (>50%) stenoses per patient, the global left ventricular function according to the systolic EF (>50%, 30–50%, < 30%), and the segmental left ventricular function with hypo-akinesia in the anterior, inferior and posterior wall.

3. Results

Quality of the teletransmitted images was considered sufficient in 98 of a total of 99 patients analyzed. One case was excluded because of the bad quality of the teletransmitted images. In nine aortocoronary bypass surgery candidates (9%), the heart surgeon required direct scrutiny of the original angiograms in order to establish the definitive diagnosis and treatment.

In five cases the teleconsulting was made in urgent context with unstable patients, waiting for heart surgery: acute type A dissecting aortic aneurysm (two patients), acute severe mitral insufficiency (one patient), acute ventricular septal defect (one patient), aortic valve endocarditis with multiple septic emboli (one patient). All these patients were urgently referred to the surgical care center based on the correct distant diagnosis made by telemedicine. In seven cases, the choice of the therapeutic approach was taken through an interactive discussion with the heart surgeon, the cardiologist and the patient.

Our overall experience of the total of the 98 patients is summarized in Table 1.

The further analysis of the prospective blinded comparison of the 47 aortocoronary bypass candidates shows that there was an excellent agreement between the diagnosis made by the direct scrutiny of the coronary angiograms and the one made with the teletransmitted images, regarding the severity of the coronary artery disease, defined as 1-2-3 vessel disease (46/47: 97.8%; $r = 0.87$, $P < 0.01$) (Fig. 1).

Also, the numbers of significant (>50%) stenoses in these 47 patients were well correlated between the two evaluation techniques: 141 detected by the direct scrutiny vs. 131 by telemedicine.

The tendency with the telemedicine was a mild overestimation of the severity of the stenosis, which led in some cases to a false positive report. This overestimation was observed especially in distal segments. Underestimation by telemedicine occurred in three cases, with significant lesions located in distal segments, not accessible to aortocoronary bypass.

For the evaluation of the global left ventricular function and segmental left ventricular function (hypo-akinesia), the concordance of the two specialists in separate hospitals was 43/47 (91%) for the left ventricular EF and 40/47 (85%) for the segmental contractility.

4. Discussion

Initial experience using non-sophisticated telemedical transmission of angiograms of cardiac surgery candidates seems to be a promising means for distantly located centers without cardiac surgery facilities [1,2,7,9]. Our results indi-

Table 1
Telemedicine for cardiac surgery candidates

	No. of patients (%)
Correct diagnosis and surgical approach	89 (91)
Urgent referral (correct distant diagnosis)	5 (5)
On-line distant consulting between cardiac surgeon and patient	7 (7)
Diagnosis established only by direct scrutiny of the original angiograms	9 (9)

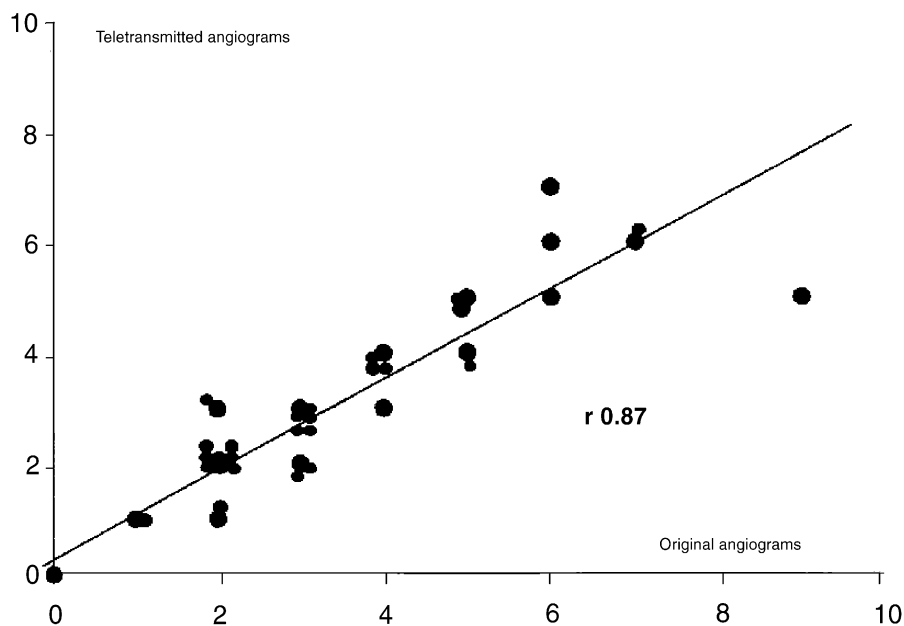


Fig. 1. Blinded comparison between numbers of significant coronary lesions detected by scrutiny of the original angiograms and teletransmitted angiograms ($r = 0.87$; $P < 0.01$).

cate that teletransmission of coronary angiograms is easy to perform and of enough quality to let the heart surgeon propose the correct diagnosis and the best therapeutic surgical approach for the patient.

This technical support of telecommunication indicates in our series that three ISDN lines system, with 384 kbit/s bandwidth transmission, gives sufficient temporal, contrast and spatial resolution for clinical diagnosis of candidates for heart surgery. The greatest advantages brought by this technique of telecommunication, in our experience, was the time gain, especially in critical patients, and the possibility to evaluate, in real time, the optimal approach with the patient in borderline situations. Our experience with this technique in heart surgery candidates cannot be extrapolated for the distant evaluation of patients with moderate coronary artery disease (i.e. candidates for percutaneous coronary angioplasty), because of the uncertain quality of resolution for the evaluation of coronary plaques and moderate stenosis. Video communication to transmit coronary images in real time in interventional cardiology needs high-quality images with the most accurate representation of cine-angiograms. Dedicated T1 line video networking of cardiac catheterization laboratories or new compression technologies like wavelet compression may be powerful tools for this purpose [12,13].

Interactive video/synchronous consultation with relatively narrow bandwidth sometimes shows images of inferior quality, especially for the resolution of details or fine movements, challenging in these cases the physician's capacity to make an accurate diagnosis [2,8,9,14]. Alternatively, data compression and bandwidth extension may avoid this problem and reduce transmission time. Digital compression JPEG (Joined Photographic Expert Group) or MPEG

(Moving Pictures Expert Group) algorithms may eliminate redundant image information and reduce the amount of data to transfer in dependence of the required quality [8,15–20]. Obviously, the costs of such sophisticated technologies are significantly more expensive when compared with technology used in our experience [21–23]. A compromise between the less expensive data compression strategy and the more expensive system bandwidth will probably be the key system for near on-line transmission of coronary angiograms.

New developments in telemedicine include Internet and Intranet connections. In fact, the focus of telemedicine has shifted in the recent years from broad-bandwidth, synchronous consultation, to more personal computer-based 'store-and-forward' systems [1,2,8,10]. Desktop facilities may become more convenient and cost-effective means of providing telemedical information transfer. These promising techniques are likely to become the most powerful communication and imaging technologies in the future, but do not allow, to our knowledge, transmission in real time of a full coronary angiogram [24].

ISDN band systems with three up to nine lines have the advantage to transmit on-line and in real-time complex dynamic images. They also allow educational programs and surgical tutorial projects, as recently performed at our institution with endovascular repair of abdominal aortic aneurysm with the backup of a tertiary care center. We further insist that in our series, the final surgical attitude was always confirmed by direct scrutiny of the original angiogram immediately before surgery. Our non-sophisticated teletransmission system may be useful as a first triage of patients in distant located centers. We underline that the final decision to operate on the patients has been always taken depending on the review of the data and clinical

evaluation of the patients by the surgeon who took full responsibility.

In conclusion, our results indicate that the ISDN transmission technique of dynamic images allows, at moderate cost, an on-line correct evaluation, in the majority of heart surgery candidates. Our teletransmission model could be useful not only in case of a very distant center but to bring forth the dialogue between cardiologists and surgeons about the 'grey area' of the indications of revascularization.

References

- [1] Stanberry B. Telemedicine: barriers and opportunities in the 21st century. *J Intern Med* 2000(247):615–628.
- [2] Grigsby J, Sanders JH. Telemedicine: where it is and where it's going. *Ann Intern Med* 1998;129:123–127.
- [3] Moore GT, Willemain TR, Bonanno R, Clark WD, Martin AR, Mogielnicki RP. Comparison of television and telephone for remote medical consultation. *N Engl J Med* 1975;292:729–732.
- [4] Bashshur RL. On the definition and evaluation of telemedicine. *Telemed J* 1995;1:19–30.
- [5] Perednia DA, Allen A. Telemedicine technology and clinical applications. *J Am Med Assoc* 1995;273:483–488.
- [6] Ghisla R, Caoduro L, Gallino A. Telemedicine in paediatric cardiology: the initial Swiss experience. *J Am Coll Cardiol* 1998;31(5 Suppl C).
- [7] Widmer S, Caoduro L, Ghisla R, Ramelli G, Taminelli F, Widmer BB, Gallino A. Tele-echocardiography in paediatric cardiology: a report of the initial experience in real world. *Eur J Paediatr* (submitted).
- [8] Becker T, Simon R. Digital image data transmission over long distances using image compression and broadband ISDN. *Computers in Cardiology*, 2001, Rotterdam, 2001.
- [9] Fogliardi R, Frumento E, Rincon D, Vinas MA, Fregonara M. Telecardiology: results and perspectives of an operative experience. *J Telemed Telecare* 2000;6(Suppl 1).
- [10] Malone FD, Athanassiou A, Nores J, Dalton ME. Effect of ISDN bandwidth on image quality for telemedicine transmission. *J Telemed Telecare* 1998;4:161–165.
- [11] Simon R, Brennecke R, Heiss O, Meier B, Reiber H, Zeelenberg C. Report of the ESC Task Force on digital imaging in cardiology. Recommendations for digital imaging in angiocardiology. *Eur Heart J* 1994;15:1332–1334.
- [12] Tobis J, Aharonian V, Mansukhani P, Kasaoka S, Jhandyala R, Son R, Browning R, Youngblood L, Thompson M. Video networking of cardiac catheterization laboratories. *Am Heart J* 1999;137:241–249.
- [13] Garratt KN. Nothin 'bet' net? (Editorial). *Am Heart J* 1999;137:187–189.
- [14] Reiber JHC, van der Zwet PM, Koning G, von Land CD, van Meurs B, Gerbrand JJ, Buis B, van Voorthuisen AE. Accuracy and precision of quantitative digital coronary arteriography: observer-, short-, and medium-term variabilities. *Cathet Cardiovasc Diagn* 1993;28:187–198.
- [15] Silber S, Dorr R, Zindler G, Preuss A, Stumpfl A. Impact of various compression rates on interpretation of digital coronary angiograms. *Int J Cardiol* 1997;60:195–200.
- [16] Koning G, Beretta P, Zwart P, Hekking E, Reiber JH. Effect of lossy data compression on quantitative coronary measurements. *Int J Card Imaging* 1997;13:261–270.
- [17] Fritsch JP, Negwer F, Renneisen U. Visual and quantitative analysis of coronary angiograms after irreversible data compression (abstract). *Eur Heart J* 1994;15(Suppl):46.
- [18] Rigolin VH, Robiolio PA, Spero LA, Margawood BP, Morris KG, Fortin DF, Baker WA, Bashore TM, Cusma ST. Lossy joint photographic expert's group (JPEG) compression of digital coronary angiograms does not affect visual or quantitative assessment of coronary artery stenosis severity. *Am J Cardiol* 1996;78:131–135.
- [19] Baker WA, Hearne SE, Spero LA, Morris KG, Marrington RA, Sketch Jr MH, Bemar VS, Kong Y, Peter RM, Bashore TM. Lossy (15:1) JPEG compression of digital coronary angiograms does not limit detection of subtle morphological features. *J Am Coll Cardiol* 1997;96:1157–1164.
- [20] Whiting JS, Eckstein M, Morioka C. Lossy image compression has insignificant effect on the accuracy and precision of quantitative coronary angiography (abstract). *Circulation* 1993;88:1652.
- [21] Kerensky RA, Cusma J, Kubilis P, Simon R, Bashore TM, Mirshfeld Jr JW, Holmes Jr OR, Pepine CS, Nissen SE. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase I: the effects of lossy data compression of diagnostic features in digital coronary angiography. *Eur Heart J* 2000;21:668–678.
- [22] Tuinenburg JC, Koning G, Hekking E, Zwindermann AH, Becker T, Simon R, Reiber JH. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase II: the effects of varying JPEG data compression levels on the quantitative assessment of the degree of stenosis in coronary angiography. *Eur Heart J* 2000;21:679–686.
- [23] Brennecke R, Bürgel U, Simon R, Rippin G, Fritsch HP, Becker T, Nissen SE. American College of Cardiology/European Society of Cardiology international study of angiographic data compression phase III: measurement of image quality differences at varying levels of data compression. *Eur Heart J* 2000;21:687–696.
- [24] ACC/ACR/NEMA Ad hoc group. American College of Radiology and industry develop standard for digital transfer of angiographic images. *J Am Coll Cardiol* 1995;25:800–802.