Assessment of the quality of neonatal echocardiographic images transmitted by ISDN telephone lines

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Abstract

***Objective*—To assess the quality of echocardiographic images from neonates transmitted over Integrated Service Digital Network 2 (ISDN2) channels.**

***Design*—Echocardiographic images were viewed live in real time either by a direct video link or by transmission over the commercial network, using one, two, or three ISDN2 channels. The order of the viewing formats was random and four observers marked each view for potential for provision of complete diagnostic information and quality.**

***Setting*—Cardiology department of tertiary referral centre for paediatric cardiac services. ISDN lines were positioned in two nearby rooms. Telephone connection was through the commercial network and video connection by a direct video cable.**

***Patients*—10 neonates were studied (weight 2600 to 3900 g). In each, nine echocardiographic studies were undertaken to assess imaging (M mode and cross sectional) and Doppler (spectral and colour) quality.**

***Results*—No significant differences were found in diagnostic ability between the different formats for M mode, colour, or spectral Doppler studies. For cross sectional imaging the diagnostic information and image quality increased with increasing numbers of ISDN channels. With six channels there was little difference from the directly connected images.**

***Conclusions*—In echocardiographic assessment of the newborn, one or two ISDN2 channels will transmit images of satisfactory quality in many situations but three or more channels are necessary to ensure minimum degradation of the live image.**

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Keywords: echocardiography; telemedicine; telephone image transfer

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Telemedicine is the remote communication of information to facilitate clinical care, most commonly the telephone transmission of images for medical diagnostic purposes. This will have its greatest application for the management of the patient with an acute problem who is being treated in a centre distant from where the necessary diagnostic expertise is available. The requirement for this is exemplified in the management the neonate with possible heart disease in whom rapid deterioration and death can occur without appropriate treatment—there are many maternity units but relatively few tertiary treatment centres. The mainstay of diagnosis is the echocardiogram, which allows rapid and detailed assessment. However, performance and interpretation require much experience and this is not available in most maternity hospitals. If guidance in performing the echocardiography and expertise in interpreting the findings are available through a distant link, neonatal paediatricians should be able to provide this service locally. Echocardiography in the newborn may pose particular difficulties for telephone transfer. The rapid heart rate, the small size of cardiac structures, and the technical difficulty of obtaining diagnostic images make it one of the most demanding specialties to which remote image transfer technology has been applied.

Transmission of video images over a telephone line requires conversion into digital format and compression of the images. The less the compression, the better the received image quality; and the greater the transmission bandwidth the less the compression required. Equipment for image transfer is commercially available for video-conferencing and can be used for medical purposes. The images can be transferred using a variable number of ISDN2 telephone lines. Each ISDN telephone line carries two channels with a bandwidth of 128 MHz. Readily available video-conferencing equipment uses two to six channels (one to three ISDN2 lines).

As we could find no definite information on differences in the diagnostic capabilities of one, two, or three ISDN2 lines for neonatal echocardiography, we studied newborn infants to assess differences in the information obtained after transmission through different numbers of channels, and to establish the likely diagnostic capabilities of each for cross sectional images, M mode studies, and spectral and colour Doppler.

Methods

Two Codec units (VS2, British Telecom, London, UK) were sited 10 metres apart in the cardiac investigation department of the Royal Hospital for Sick Children, Glasgow. Each was connected to the standard British Telecom (BT) telephone network through a link allowing calls to be made using one, two, or three ISDN2 lines. Calls between them were routed through the BT network in the standard commercial manner, so this exactly simulated

Table 1 Studies performed on each patient

Study	*Echocardiographic feature*	*Ultrasound mode*
1	Long axis left ventricle and aorta	Cross sectional
2	M mode aorta and left atrium	M mode
3	4 chamber view of crux of heart	Cross sectional
4	4 chamber view pulmonary vein flow	Colour
5	Short axis great arteries	Cross sectional
6	Spectral of pulmonary artery flow	Spectral
7	Ductal view on colour	Colour
8	Ductal spectral signal (if present)	Spectral
9	Aortic arch	Cross sectional

Studies 1 and 2, 3 and 4, 5 and 6, and 7 and 8 were undertaken using the same line format before it was changed.

transmission from a distant site to a centre. SVHS connections were used from the ultrasound machine (Vingmed CFM 800, Vingmed Sound, Horten, Norway) to the transmitting Codec unit and from the receiving Codec unit to the television monitor. In addition a 12 metre video cable was used to connect the ultrasound machine directly to the receiving monitor.

Nine echocardiographic views or features were assessed for diagnostic quality and allocated to an ultrasound mode (table 1). Studies were transmitted through the direct video connection or the telephone network and assessed live by a panel of four observers. The transmission format (direct or by one, two, or three ISDN2 lines) was not known to the observers, and the order in which each of the formats was sent was allocated randomly. The studies were performed by a senior echocardiographer and assessed by a senior echocardiographer, two consultant paediatric cardiologists, and a senior paediatric cardiology registrar.

Each cross sectional study was scored as to whether or not it provided sufficient information to allow it to be clearly defined as normal or whether there were some aspects—such as echo drop out or image blurring—that prevented the observer being certain that the image had been shown to be completely normal. M mode and spectral signals were assessed as to whether an accurate measurement could be made, and colour Doppler was assessed for the diagnostic quality of the image in recognising pulmonary vein flow and allowing a clear statement to be made as to whether it was possible to exclude or diagnose an arterial duct. In the last five infants the assessors also gave a subjective mark from 1 to 5 in an attempt to make a more detailed assessment of the differences in quality.

Ultrasound studies were undertaken in 10 normal newborn infants, weight 2400 to 3900 g. The duct was open in only two infants, and one had a small muscular ventricular septal defect which was recognised by the observers on imaging before colour was used.

Table 2 Demonstration of the number of images considered unsatisfactory in relation to the total number of each image viewed for each transmission format

	Direct video	*Three channels*	*Two channels*	*One channel*
Cross sectional	5/160 (3%)	9/160 (6%)	13/160 (8%)	32/160 (20%)
M mode	0/40 (0%)	0/40 (0%)	0/40 (0%)	0/40 (0%)
Colour Doppler	2/80 (3%)	2/80 (3%)	2/80 (3%)	3/80 (4%)
Spectral Doppler	0/48 (0%)	0/48 (0%)	1/48 (2%)	0/48 (0%)

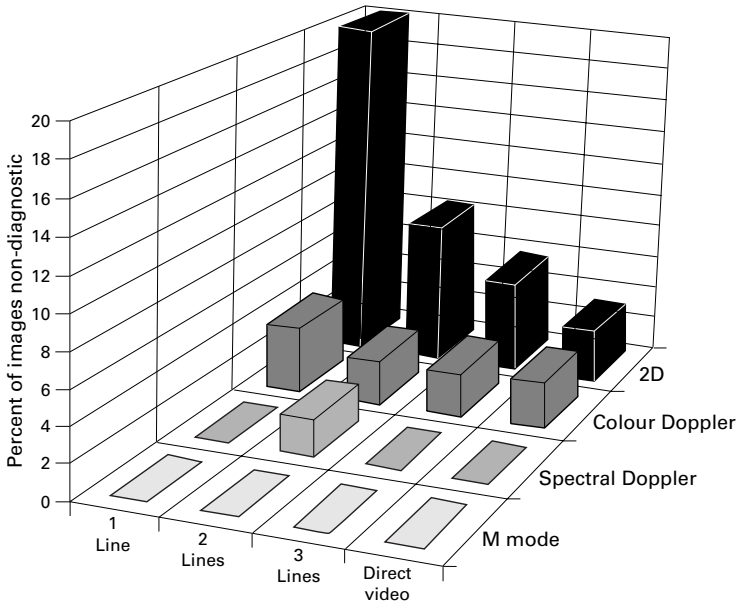

Figure 1 The percentage of images considered to be non-diagnostic for each echocardiography technique and each transmission mode.

Results

DIAGNOSTIC QUALITY

For each of the four ultrasound modes the results were evaluated as to whether they were of diagnostic quality (defined above) or not. The results are presented in table 2 as the ratio of the number considered to be of below diagnostic standard to the total number of studies performed for each of the four ultrasound modes. They are further depicted graphically in fig 1 as the percentage of non-diagnostic studies. The possible score for cross sectional imaging was obtained by adding those for long axis, four chamber, great artery, and aortic arch views to give a possible total of 160 (that is, 4 views × 10 patients × 4 observers). Analysis of the cross sectional results using Fisher's exact test showed that images transmitted over one ISDN2 link were more often non-diagnostic than those transmitted over two lines ($p < 0.005$, odds ratio 4.19) or three lines

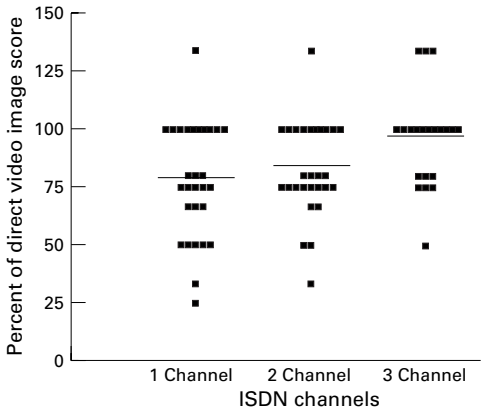

Figure 2 Image quality analysis of colour flow Doppler images transmitted over one, two, and three channel ISDN2 lines.

Table 3 Percentage scores of different cross sectional echocardiographic views

	One channel		*Two channel*		*Three channel*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Long axis	65	30.1	72.4	35.8	113.6	46.3
Four chamber	50	27.9	73.7	31.2	94.3	38.1
Short axis	73.2	60.7	60.7	58	82.6	54.7
Arch	73.8	20.2	72.3	18.7	104.4	21.3
Total	64.5	38.3	73.4	38.0	97.1	43.0

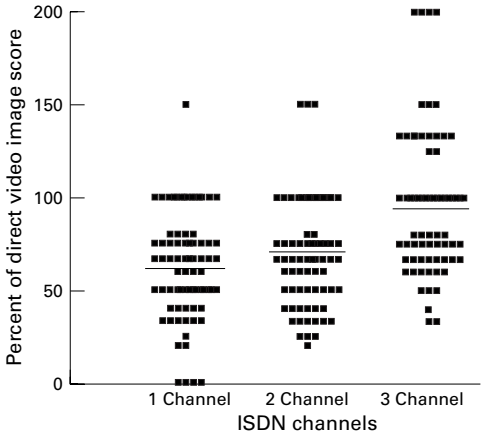

Figure 3 Combined percentage scores of all four cross sectional echocardiographic views.

($p < 0.0002$, odds ratio 2.83). There was no significant difference in the diagnostic quality of the image between the direct video link and two or three channel ISDN2 links. The aortic arch view was considered to be diagnostic in all modes by all observers. The spectral and M mode studies were considered diagnostic using all transmission methods, with only one spectral study (using two ISDN2 lines) considered to be suboptimal. The quality of the colour Doppler signals was found to be diagnostic, with no recognisable differences between the transmission modes.

IMAGE QUALITY

In the second five patients each study was allotted a subjective quality grade of 1 to 5. For each observer the direct video transmission acted as an internal control. The scores for the three different ISDN2 channels were expressed as a percentage of the direct video score. Differences in quality were then compared for each image mode using repeated measures analysis of variance.

M mode and spectral Doppler grading showed no observer detectable difference between the different transmission modes tested. Colour flow Doppler images received over a three line ISDN2 link were considered to be of better quality than those transmitted by one channel ($p < 0.001$) or two channel lines ($p < 0.05$), with no detectable difference between the latter two (fig 2).

The percentage scores for cross sectional images from the four echocardiographic planes are presented in table 3. Three line ISDN2 transmission produced better quality images than one or two line for long axis, four chamber, and arch views ($p < 0.05$–0.001). For the short axis view, the number of ISDN2 lines used had no observer detectable effect on image quality. The use of two lines compared with one produced better quality images when examining four chamber views ($p < 0.05$). Overall the use of a three line ISDN2 system produced better cross sectional images than one line ($p < 0.001$) or two lines ($p < 0.001$) (fig 3).

Discussion

Telemedicine is considered to be an important development for the NHS in the United Kingdom to ensure equality in the provision of care to areas distant from specialist services. This has been highlighted in the report sponsored by the Department of Health, the Welsh Office, and the Department of Trade and Industry, which states that most believe that the technique has been proved clinically and technically.[1] In relation to the specialty of cardiology the report discusses ECG transfer but makes no mention of echocardiography although it comments that transmission of live video images is a complex and changing area. Although modern echocardiographic equipment records images in a digital format that can be transmitted over a telephone line without any degradation in image quality, this takes more time than acquisition and images cannot be viewed in real time. If the echocardiographer has limited experience and requires guidance in obtaining and interpreting the appropriate images, real time transmission is necessary. The relevance of this to neonatal cardiology in the United Kingdom has recently been highlighted with the suggestion that more support should be given to neonatologists performing echocardiography.[2] Where the neonatologist lacks experience, the provision of expert backup through a telemedicine link would be most helpful and might obviate the travel of the cardiologist to the neonatal unit or the infant to the cardiac centre.

Telephone transfer of paediatric echocardiographic images was shown to be a practical technique by Canadian workers in 1989[3] and this was subsequently confirmed in the USA[4 5] and the United Kingdom,[6] with studies on the fetus also being possible.[7] However, we are not aware of any published study in which the relative merits of different bandwidths has been reported. The findings confirm work by others that this commercially available equipment can provide images of diagnostic quality, even if only one ISDN2 line is used. There is little to be gained with more lines for situations with a slow frame rate such as colour Doppler and spectral and M mode studies. However, for cross sectional images transmission through more lines may be required to ensure reliable diagnosis by less experienced operators. This suggests that a regional centre undertaking such a service should consider the use of at least three ISDN2 lines.

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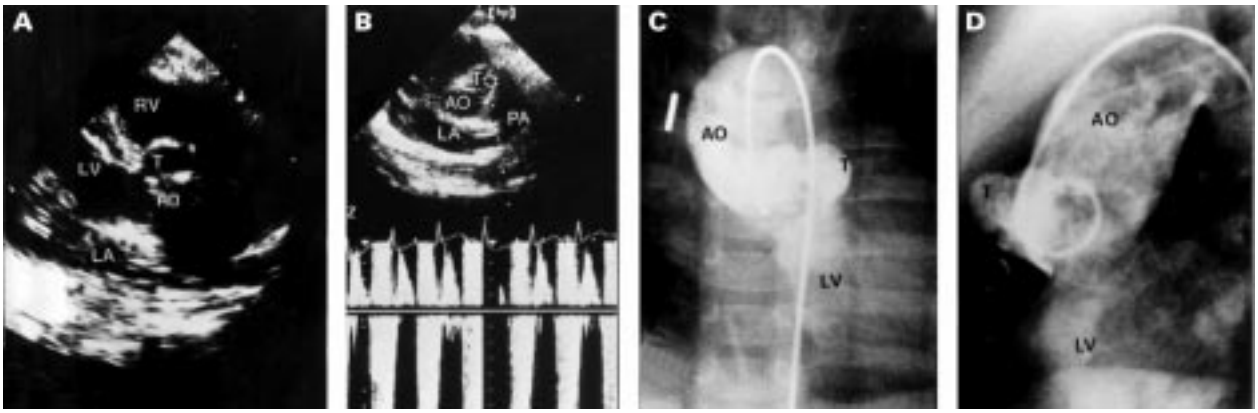
IMAGES IN CARDIOLOGY

Aorto-left ventricular tunnel

Aorto-left ventricular tunnel (T) is an abnormal communication between the ascending aorta and the left ventricle. The tunnel bypasses the normal ventriculoarterial junction but does not penetrate the septal musculature. The aortic orifice is distal to the level of the sinutubular junction, whereas the ventricular orifice is situated within the interleaflet triangle between the right and left aortic valvar leaflets.

This is in contrast with a sinus of Valsalva aneurysm, which originates proximal from the sinutubular junction within the right or noncoronary sinuses, seldom from the left. In the patient reported here a basically similar morphology of the tunnel was seen. After detection of a systolic–diastolic murmur in the 2nd month of life, cross sectional echocardiography and colour flow mapping confirmed an aorto-ventricular tunnel. (A) Echocardiography in the parasternal long axis view showing the extent of the tunnel between the aorta and left ventricle. (B) Parasternal short axis view demonstrating the tunnel and the Doppler flow forward into the aorta and regurgitant into the ventricle. (C) Anteroposterior view and (D) the lateral view of the thoracic aortogram showing the tunnel with a large extracardiac aortic wall aneurysm. (RV, right ventricle; LV, left ventricle; AO, aorta.)

Surgical correction was performed at the age of 19 months by double patch closure of the tunnel, preserving blood flow to the hypoplastic right coronary artery originating from the lateral wall of the tunnel. Twenty months after the operation there was grade I–II aortic incompetence.



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