High-grade Video Compression of Echocardiographic Studies: A Multicenter Validation Study of Selected Motion Pictures Expert Groups (MPEG)-4 Algorithms

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Background: **Large files produced by standard compression algorithms slow down spread of digital and tele-echocardiography. We validated echocardiographic video high-grade compression with the new Motion Pictures Expert Groups (MPEG)-4 algorithms with a multicenter study.**

Methods: **Seven expert cardiologists blindly scored (5-point scale) 165 uncompressed and compressed 2-dimensional and color Doppler video clips, based on combined diagnostic content and image quality (uncompressed files as references). One digital video and 3 MPEG-4 algorithms (WM9, MV2, and DivX) were used, the latter at 3 compression levels (0%, 35%, and 60%).**

Results: **Compressed file sizes decreased from 12 to 83 MB to 0.03 to 2.3 MB (1:1051-1:26 reduction ratios). Mean SD of differences was 0.81 for intraobserver variability (uncompressed and digital video files). Compared with uncompressed files, only the DivX mean score at 35% (P = .04) and 60% (P = .001) compression was significantly reduced. At subcategory analysis, these differences were still significant for gray-scale and fundamental imaging but not for color or second harmonic tissue imaging. Original image quality, session sequence, compression grade, and bitrate were all independent determinants of mean score.**

Conclusions: **Our study supports use of MPEG-4 algorithms to greatly reduce echocardiographic file sizes, thus facilitating archiving and transmission. Quality evaluation studies should account for the many independent variables that affect image quality grading.** (J Am Soc Echocardiogr 2007;20: 527-536.)

Digital echocardiographic machines produce large databases: 30 MB/s (at 30 frames/s) result in 25 to 30 GB for a 15-minute study.[1] Thus, there is a need for both clinical and digital image compression to reduce storage costs and impact of transmission over networks. Clinical compression–storage of significant, short video sequences[2]–has been validated, reduces storage space by as much as 30-fold, but relies heavily on operator expertise. Numerous digital compression modalities have been validated to reduce file sizes. Because lossless compression (reduction of redundant image information) achieves minor reductions in data size (up to 3:1 compression ratio), a number of lossy compression algorithms have been developed that eliminate as much data as possible from images without significant impact on diagnosis. Joint Photographic Experts Group (JPEG) compression, incorporated into the Digital Imaging and Communications in Medicine (DICOM) 3.0[3] standard (a set of rules that dictates how images are exchanged between computers and medical devices), is ideal for short video sequences (loops).[2,4] However, initial hardware and software costs and the relatively large files produced by JPEG lossy compression slow down spread of digital echocardiography.

Recently, a number of newer lossy Motion Pictures Expert Groups (MPEG)-4 compression algorithms have been introduced (some freely available on the Internet) that allow high compression rates in low and middle bitrate ranges. However, their use in medicine is still limited[5,6] and–most importantly–high-grade MPEG-4 lossy compression has not been validated in echocardiography. The aim of our study was to compare the ability of 3 selected MPEG-4 algorithms to produce a consistent reduction in 2-dimensional and color Doppler motion video data size without significantly reducing image quality and diagnostic content, as assessed by the human eye.

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Table 1 Original video sequences

	Modality		View		Description	Diagnostic content to be evaluated
1	TT	2D	Parasternal long-axis	N	Normal biologic mitral valve prosthesis	Resolution and mobility of prosthesis cusps; resolution of ventricular endocardium; texture of ventricular myocardium; analysis of segmental wall motion
2	TT	Color Doppler	Parasternal long-axis	N	Normal biologic mitral valve prosthesis	Color Doppler analysis of flow through prosthesis; diagnosis of normal function of valve prosthesis
3	TT	Color Doppler	Apical 4-chamber	N	Mild mitral valve regurgitation	Description of color Doppler pulmonary venous and transmitral flow velocities; description of mild mitral valve regurgitation and mild proximal isovelocity acceleration; description of physiologic low velocity intraventricular flow
4	TT	Color Doppler	Parasternal short-axis	N	Mild mitral valve regurgitation	Description of regurgitant orifice; differentiation between mitral regurgitation and color Doppler artefacts
5	TT	2D	Apical 4-chamber	II	Mild mitral valve stenosis	Resolution of mitral valve leaflets with mild fibrosis and their mobility; diagnosis of mild mitral valve stenosis
6	TE	2D	Upper esophagus, long-axis	N	Mild aortic valve stenosis	Resolution of mild aortic valve fibrosis; description of cusp mobility; anatomy of left ventricular outflow tract; structure of aortic root walls; anatomy of sinuses of Valsalva and sinotubular junction; diagnosis of mild aortic valve stenosis
7	TE	2D	Lower esophagus, 2-chamber	N	Mitral valve vegetation	Resolution of mobile mass on mitral valve leaflets; differentiation between structure of mass and of valve leaflets; diagnosis of valve vegetation
8	TT	2D	Parasternal long-axis	N	Normal myocardial ventricular structure and valve tissues	Resolution of ventricular endocardium; texture of ventricular myocardium; wall-motion analysis; resolution of mitral valve leaflets and aortic valve cusps; description of normal anterior pericardial function
9	TT	2D	Parasternal long-axis	II	Mild systolic prolapse of mitral posterior valve leaflet	As above, with addition of description of mild mitral valve prolapse (posterior leaflet)
10	TT	Color Doppler	Parasternal short-axis	N	Periprosthetic mitral valve regurgitation	Diagnosis and short-axis mapping of mild periprosthetic mitral valve regurgitation (lateral); description of normal anterograde mitral prosthetic flow velocities
11	TT	2D	Parasternal short-axis	II	Ischemic dilated cardiomyopathy	Resolution of ventricular endocardium; texture of myocardium; analysis of segmental wall motion; diagnosis of ischemic dilated cardiomyopathy

N, Native imaging; *TE*, transesophageal examination; *TT*, transthoracic examination; *2D*, 2-dimensional; *II*, second harmonic tissue imaging.

METHODS

Source Videofiles

We selected 11 motion video single cardiac cycle clips of normal and common pathologic echocardiographic findings, using standard transthoracic and transesophageal views, native and second harmonic tissue imaging, and gray scale and color Doppler imaging, focusing on areas requiring good resolution for clinically acceptable (diagnostic) judgment (Table 1 and Figure 1). M-mode and spectral Doppler images were not included in the study.

Uncompressed source files were obtained by storing study video clips on the digital memory of an ultrasound unit (Sonos 4500, Philips, Andover, Mass). Using frame-by-frame playback, each frame was transferred through the super-VHS video output to an analog-to-digital video (DV) conversion card (MovieBox DV, Pinnacle Systems, Mountain View, Calif) and stored on a personal computer as a bitmap file, preserving original video format (24-bit color, 720- × 576-pixel resolution) (Figure 2).[1] Source files were reconstructed joining frames in an audio-video interleave (AVI) file at 15 or 25 frames/s, depending on original frame resolution. Uncompressed AVI video clips were

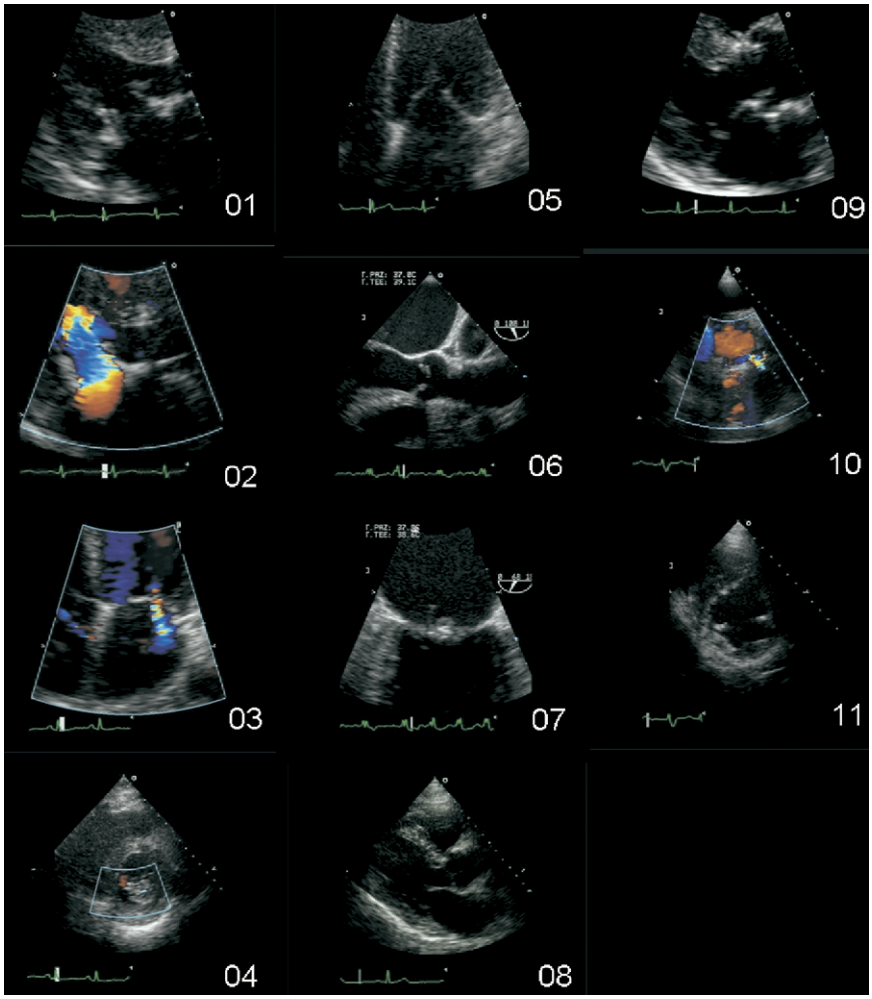

Figure 1 Original video files. *1*, Transthoracic (TT), 2-dimensional (2D), parasternal long-axis view (mitral valve level), normal mitral valve biologic prosthesis; *2*, TT, color Doppler, parasternal long-axis view, mitral valve biologic prosthesis; *3*, TT, color Doppler, apical 4-chamber view, mild mitral valve regurgitation; *4*, TT, color Doppler, parasternal short-axis view (mitral valve level), mild mitral valve regurgitation; *5*, TT, 2D, apical 4-chamber view, mild mitral valve stenosis; *6*, Transesophageal, 2D, upper esophageal long-axis view of aortic valve, mild aortic valve stenosis; *7*, Transesophageal, 2D, lower esophageal 2-chamber view, mitral valve vegetation; *8*, TT, 2D, parasternal long-axis view, normal myocardial and valvular structures; *9*, TT, 2D, parasternal long-axis view, mild mitral valve prolapse (posterior leaflet); *10*, TT, color Doppler, parasternal short-axis view (mitral valve level), mitral mitral paraprosthetic valve regurgitation; *11*, TT, 2D, parasternal short-axis view (papillary muscles level), ischemic dilated cardiomyopathy.

considered the gold standard to which to compare the compressed clips.

Video Compression

We used freeware (Virtualdub, Version 1.4.8, www.virtualdub.org) to compress and edit the video files to eliminate all information surrounding the image sector, excluding audio. Applying manufacturer-suggested configuration parameters (Table 2), we used the DV codec (Digital Video, Adaptec DV Soft, Adaptec Inc., Milipitas, Calif) (single predetermined compression level) and 3 MPEG-4 codecs (WM9, MV2, and DivX) (Microsoft Inc., Redmond, Wash) at 3 different compression levels (0%, 35%, and 60%), maintaining original image format (24-bit color, 720 × 576 pixel) and frame rate. The 3 chosen compression values were defined as the complementary value of video clip quality after compression (on a 0%-100% scale) specified by each codec manufacturer. Specifically, 100%, 65%, and 40% video quality after compression has been respectively redefined as 0%, 35%, and 60% compression level. Uncompressed and compressed image files were all randomly added to a test sequence to be evaluated by the observers. However, 3 identical files of each uncompressed and of each DV file were added to the test sequence. Because

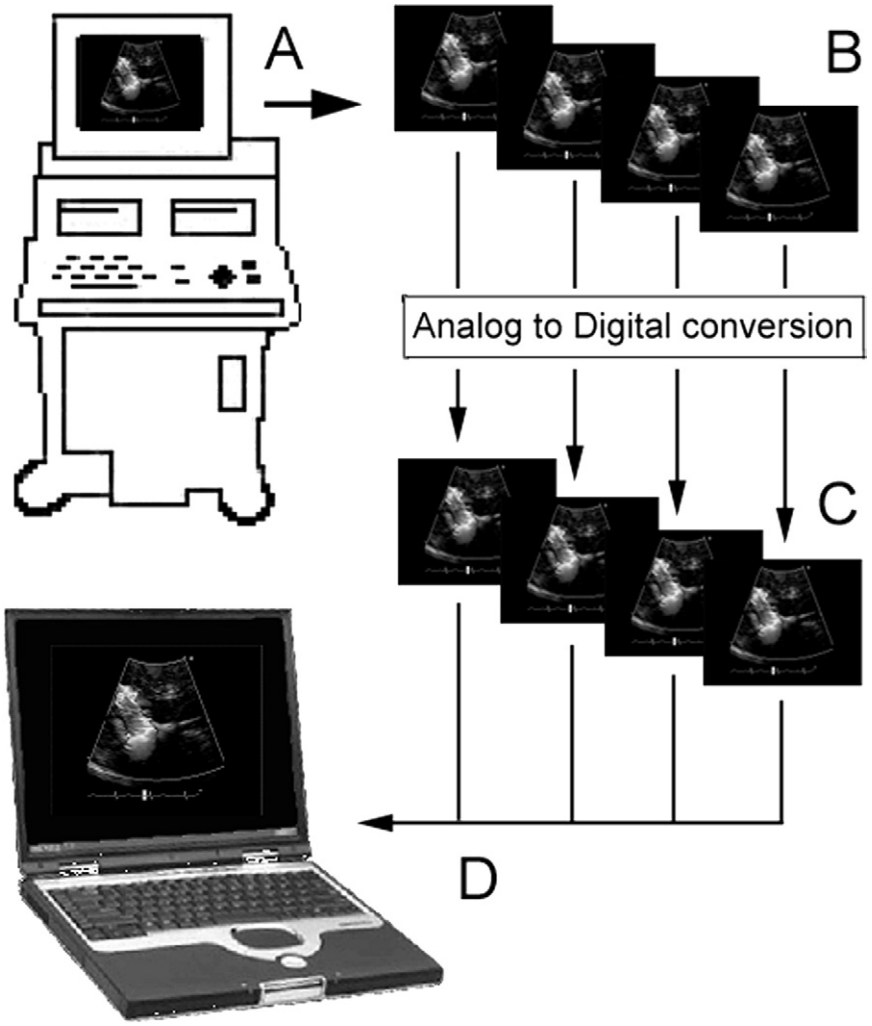

Figure 2 Uncompressed files construction. **A**, Echocardiographic machine. **B**, Frame-by-frame playback of original uncompressed video clip (uncompressed high-resolution video). **C**, Each single frame of original video is digitized in bitmap format, preserving original video format (24-bit color, 720- × 576-pixel resolution), using super-VHS video output of echocardiographic machine and analog to digital (digital video stream) video conversion card. **D**, Sequence of bitmap-format video frames is stored on personal computer. Finally, each original file is reconstructed by joining bitmap frames to create audio-video interleave (*AVI*) file at 15 or 25 frames/s, depending on frame resolution.

the origin of the files was not recognizable, the observers evaluated each uncompressed and each DV file 3 times, allowing for analysis of interobserver and intraobserver variability (see "Statistical Analysis" section). We obtained 15 files from each original AVI video clip and a total of 165 files, which were evaluated blindly by 7 cardiologists (observers), each exceeding 10 years experience in echocardiography, from 4 tertiary care referral centers of the Milano area (Lombardia, Italy).

Video Scoring

Playback of the video clips was performed on a computer (Windows 2000 Professional operating system, Microsoft Inc.), configured with a 15-in screen display at 1280- × 1024-pixel resolution, 1.5-GHz processor (Pentium IV, Intel Corp., Santa Clara, Calif), 500 MB of RAM, and a 64-MB video memory card, using software (Windows Media Player, Version 9, Microsoft Inc.). Observers scored video files using a modified 5-point Likert scale (Table 3), taking into consideration: image diagnostic content (ie, feasibility of diagnostic interpretation from the image) as described in Table 1; image quality (ie, general quality; gray-scale representation; smoothness and quality–yield–of color flow velocities; pixeling effects)[7]; and image resolution (ie, the sharpness or edge definition of a structure and its clear separation from other structures). Before testing, each observer was asked to undergo a training session, during which the score assigned to each image was discussed;

Table 2 Compression algorithms

Codec	Configuration parameters
DV	
Digital video (Adaptec DVSoft)	Display type = auto detect; video file setting = both fields
WM9	
Microsoft Windows Media Video 9 (MPEG-4)	Video = quality VBR; video quality = 100% (compression level = 0%); 65% (compression level = 35%); 40% (compression level = 60%)
MV2	
Microsoft MPEG-4 Video Codec V2	Compression control = 75%; data rate (Kb/s) = 6000 (compression level = 0%); 900 (compression level = 35%); 350 (compression level = 60%)
DivX	
DivX Networks codec 4.11 (MPEG-4)	Variable bitrate mode = 1-pass quality based; performance/quality = medium; encoding quality = 100% (compression level = 0%); 65% (compression level = 35%); 40% (compression level = 60%)

MPEG, Motion Pictures Expert Groups; *VBR*, variable bit rate.

Table 3 Scoring scale for video sequences

Score	Overall quality of video sequence	Description
5	Excellent	Excellent (optimal) image quality
4	Good	Good image quality
3	Fair	Usable, adequate visualization
2	Mediocre	Suboptimal image quality
1	Poor	Cannot be used/interpreted

training was performed on a separate set of uncompressed and compressed randomized images, one for each analyzed echocardiographic modality (2-dimensional, second harmonic tissue imaging, color Doppler), and separately for transthoracic and transesophageal imaging. Testing was performed on 3 sequential evaluation sessions each lasting 30 minutes, on alternate weeks. The evaluation room was darkened to avoid reflections on the computer screen and improve contrast; typical viewing conditions for echocardiography and parameters of monitor brightness and contrast were held constant. For each compressed video file, we noted: compression level (%); compression ratio (=uncompressed video file dimension/compressed dimension); dimensions (Kb); and bitrate related to compression level (Kb/s). Based on the obtained mean score, all uncompressed video files were arbitrarily categorized into two groups: as optimal (7 video files, mean score > 3.4) or suboptimal (4 video files, mean score ≤ 3.4) image quality.

Statistical Analysis

Mean quality scores (from the 7 observers) were computed for each file and compared across the 3 compression levels with analysis of variance statistics using uncompressed files scores as controls (Dunnet's method) for the whole video database and on selected subgroups: gray level, color Doppler, native, or second harmonic tissue imaging, and suboptimal or optimal original image quality (see above). Stepwise multiple regression analysis was used to screen for significant predictors (evaluation score, original video quality, compression grade, codec, bitrate, echocardiographic view, evaluation session, examination mode, color imaging, second harmonic tissue imaging, analyzed anatomy, original image frequency in hertz) of image quality scoring. Repeated scoring of uncompressed and DV files was used to test intraobserver (between evaluation sessions 1 and 2, 1 and 3, and 2 and 3) and interobserver variability with Bland-Altman analysis. Intraobserver variability was also assessed using: (1) intraobserver percent agreement on neighboring scores, where a difference of at least 2 score points was required for discordance (eg, from 1 to 3, but not from 2 to 3); and (2) an index of weighted percentage agreement,[8] a score based on the frequency and relative weight at each level of agreement between two evaluations (sessions 1 and 2, 1 and 3, and 2 and 3) made by the same observer. Statistical analysis was performed using software (SPSS Inc, Version 8.0, SPSS Inc., Chicago, Ill).

RESULTS

File Dimensions

Analysis of video clips produced a total of 1155 data points. File dimensions range decreased from 12 to 83 MB (uncompressed video clips) to 0.03 to 2.3 MB (compression ratios: 1:1051 to 1:26 across the different codecs used). Table 4 shows the compression characteristics for a sample video file: bitrates and compression ratios varied depending on the codec used, resulting in different video file dimensions after compression. Overall, the smallest file dimensions at 60% compression level were achieved using the WM9 (79 ± 46 Kb) and DivX (74 ± 40 Kb) codecs, followed by the MV2 codec (133 ± 81 Kb). However, at both 35% and 60% compression levels, there were no significant differences between file dimensions using the different MPEG-4 codecs (WM9, MV2, and DivX).

Image Quality Scoring

Different scoring patterns could be recognized between observers (Table 5): observers 1 and 7 were respectively the most and the less severe on image quality requirements. The latter graded 54.5% of

Table 4 Compression characteristics of a sample video file

Video file	Codec	Compression grade	Kb	Bitrate	Compression ratio
1	Uncompressed original video clip	—	51,038		1
	DV	0%	5914		9
	WM9	0%	1533	7264	33
	WM9	35%	213	969	240
	WM9	60%	104	460	491
	MV2	0%	414	246	123
	MV2	35%	324	193	158
	MV2	60%	148	89	345
	DivX	0%	1062	632	48
	DivX	35%	192	114	266
	DivX	60%	96	57	532

DivX, DivX Networks codec 4.11 (MPEG-4); *DV*, digital video (Adaptec DVSoft); *MV2*, Microsoft MPEG-4 Video Codec V2; *WM9*, Microsoft Windows Media Video 9 (Motion Pictures Expert Groups [MPEG]-4).

Table 5 Frequency distribution of scores by observer

Assigned score		Observer 1	2	3	4	5	6	7
1	%	7.9	0	0	1.8	1.8	0	0
2	%	**53.3**	7.9	8.5	13.9	10.9	1.8	3
3	%	30.9	30.3	**46.1**	**35.8**	**45.5**	19.4	40
4	%	7.9	**40.6**	35.8	30.3	33.1	**47.9**	**54.5**
5	%	0	21.2	9.7	18.2	8.5	30.9	2.4
Total		100	100	100	100	100	100	100

The highest scores assigned by each observer are in boldface.

the files as good (score 4) image quality, whereas the former scored 53.3% of the files as mediocre (score 2) quality, including the uncompressed files (which displayed the highest possible image quality). Analysis by observers 2, 3, 4, 5, and 6 was more balanced along the scoring scale.

Figure 3 plots mean scores for each codec at each compression level used, in comparison with uncompressed files. Encoding with DV was undistinguishable from the original uncompressed files. Scores for WM9 and MV2 codecs at all compression levels were also not different from uncompressed data, whereas the DivX codec scored lower at 35% (P = .04) and 60% (P = .001) compression levels. Interestingly, when subgroup analysis was performed, all scoring differences for the DivX codec disappeared within color Doppler, second harmonic tissue imaging, and suboptimal original imaging quality subgroups.

At multivariate analysis (Table 6), several factors independently influenced mean score (quality of original video sequence, evaluation session, compression grade, and compression bitrate). The relative importance of the session factor in the evaluation process is evidenced also in Table 7: the mean score decreased significantly between sessions 1 and 3 in 5 of 7 observers.

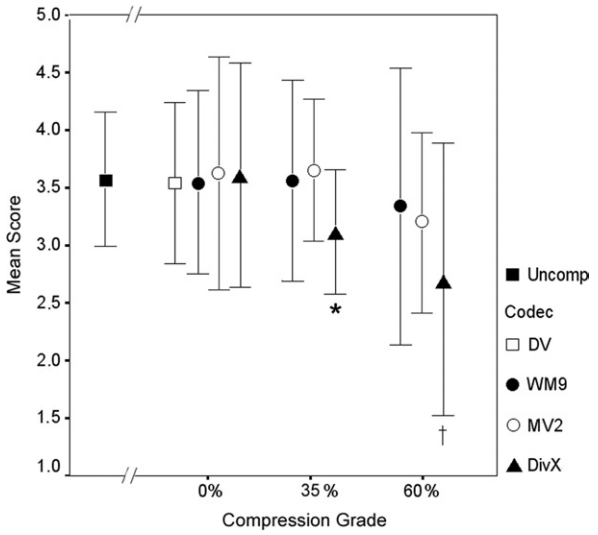

Figure 3 Compression scoring. Mean score (blind evaluation based on 5-point scale quality rating) obtained for each video compression codec used, in comparison with uncompressed (*uncomp*) reference video files. Digital video (*DV*) codec is evaluated at only available (low) compression level (factory preset). Three MPEG-4 codecs (DivX, MV2, and WM9) are evaluated at 3 incremental compression grades, based on configuration documentation of each codec. *P = .04; †P = .001.

Variability Analysis

There were no significant differences in mean scores at repeated blind evaluation, during 3 sequential sessions, for both uncompressed and DV files. At Bland-Altman analysis for intraobserver variability, the SD of the differences ranged from 0.6 to 1.25, with a mean of 0.81 Thus, the limits of agreement were ±1.62, indicating that the mean scoring resolution (pooling all observers) on the 5-point scale used was approximately 1.5 points. The SD of the differences for interobserver variability ranged from 0.77 to 1.36. Intraobserver percent agreement on neighboring scores (see "Methods"

Table 6 Multivariate regression analysis

Dependent	*r*	*P*	Predictor	B	SE	*P*
Mean score	.71	<.001	1. Original video quality	−0.6	0.04	<.001
			2. Evaluation session	−0.2	0.08	<.001
			3. Compression grade	−0.15	0.05	<.001
			4. Bitrate	0.005	0.0001	.001
Constant				4.8	0.13	<.001

Table 7 Mean score assignment by session by observer

	Observer						
Score	1	2	3	4	5	6	7
Session 1							
Mean	2.65	3.69	4.11	3.85	3.7	4.33	3.54
Median	3	4	4	4	4	4	4
Mode	2	4	4	4	4	4-5	4
SD	0.7	0.82	0.69	0.83	0.79	0.67	0.64
Session 2							
Mean	2.27*	3.85	3.36‡	3.36*	3.33*	4.15	3.6
Median	2	4	3	3	3	4	4
Mode	2	3-4	3-4	3	3	4	4
SD	0.71	0.87	0.65	1.02	0.98	0.7	0.6
Session 3							
Mean	2.25†	3.71	2.95‡	3.27†	3.05‡	3.77‡	3.55
Median	2	4	3	3	3	4	4
Mode	2	4	3	3	3	4	4
SD	0.77	0.95	0.52	1.05	0.64	0.79	0.57

*$P < .05$, †$P < .01$, ‡$P < .001$ vs session 1.

Table 8 Intraobserver percent agreements

	Evaluation sessions			Means by observers
	1 vs 2	2 vs 3	1 vs 3	
Observer	±1 Score (%)	±1 Score (%)	±1 Score (%)	±1 Score (%)
1	100	81.9	91	91
2	72.8	100	91	87.9
3	91	91	72.8	75.8
4	81.9	91	72.8	78.9
5	100	91	72.8	87.9
6	100	100	100	100
7	100	100	100	100
Means by sessions	92.2	93.6	85.8	
Total means				88.8

section) was greater than 73% for all observers (Table 8). With the exception of one observer (No. 4) all other showed increasing intraobserver agreement in subsequent sessions. The index of weighted percentage agreements at blind repeated evaluation of uncompressed and DV files for each observer were: observer 1, 84.8%; observer 2, 75.8%; observer 3, 77.3%; observer 4, 77.3%; observer 5, 69.7%; observer 6, 93.9%; and observer 7, 83.3%.

DISCUSSION

Our multicenter study is the first to validate MPEG-4 compression algorithms in clinical echocardiography, and demonstrates that very high compression grades are achievable without significant degradation of image quality or loss of diagnostic content. Further, both the type of codec and the imaging modality used determine the perceived quality of the compressed image.

Digital and Tele-echocardiography

When economically feasible, digital echocardiography has obvious advantages: reduced storage volume, facilitated laboratory work flow, random access to imaging data for local or remote review, side-by-side comparison, postprocessing and accurate/easy quantitative analysis, superior resolution especially in time, greater portability (transmission over networks), and consequent feasibility of tele-echocardiography,[9-13] which greatly expands the possibilities of the echocardiography laboratory.[11,14,15] However, echocardiographic images are still commonly stored on super-VHS videotape worldwide.

The decreasing costs of digital technology and the increasing use of the DICOM standard for image format are fostering the use of digital echocardiography, although two problems limit this expansion: (1) storage space required by the large video files produced by previously validated JPEG (within DICOM), and MPEG-1 and MPEG-2 (outside DICOM) compression algorithms[16-18]; and (2) the high costs of high-bandwidth lines necessary to transmit this large amount of data. Broad territorial deployment of these lines is currently still underdeveloped in many areas of the world.

A practical answer to these problems would be to combine the use of the newer MPEG-4 compression algorithms with ubiquitous low-cost, low-bandwidth data lines as the Integrated Service Digital Network (ISDN) or Asymmetric Digital Subscriber Line (ADSL) telephone lines. High-grade MPEG-4 compression would enable transmission of echocardio-

graphic studies with a store-and-forward mechanism using a single ISDN line (128-Kbps bandwidth), which does not require replacement of existing telephone networks (as opposed to high-speed data networks that require specialized digital transmission lines and decoding technology).[16] Previous works have established the reliability of echocardiographic imaging transmission using ISDN technology.[19-21]

MPEG-4 Compression

We used a standard subjective assessment of video quality and diagnostic content by a group of experienced cardiologists to assess: (1) differences in diagnostic motion video compression quality by different MPEG-4 codecs; and (2) the highest level of compression, for each codec, that would preserve diagnostic and image quality as perceived by the human eye.

It has been demonstrated that MPEG-1 and MPEG-2 algorithms compress data at an effective ratio of, respectively, 200:1 and 48:1 with no degradation in endocardial visualization[17,22] when compared with imaging recorded on super-VHS videotape (lower quality compared with the original digital echocardiographic imaging). Our data demonstrate that MPEG-4 algorithms achieve an impressive amount of motion video lossy data compression (>1:1000) with no or minor decrease in image quality or diagnostic content when compared with uncompressed digital imaging, irrespective of imaging modality and of the original image quality. Further, our results indicate that even higher compression levels can be obtained with original suboptimal imaging or when using color Doppler or second harmonic tissue imaging, meaning that subjective scoring was dependent on the original image resolution (lower in color Doppler and suboptimal images)–as confirmed by regression analysis–and gray levels display (lower in second harmonic tissue imaging). Thus, images with lower quality or resolution can achieve higher compression without degradation.[23] Therefore, MPEG-4 compression can preserve image quality, fine anatomic details, gray-scale extension, and color Doppler smoothness, while minimizing pixeling effect.

Interestingly, a learning factor was demonstrated during the evaluation process: the majority of observers became more severe in the evaluation sessions after the first. This finding suggests that image quality evaluation studies in echocardiography should average multiple evaluation sessions.

Perceived quality of MPEG-4 compressed video was dependent on both degree of compression and type of codec used: the DivX compression progressively deteriorated image quality. Thus, the results of our study cannot be extrapolated to all available codecs. Given the rapid turnover of the MPEG-4 codecs on the market as technology evolves, and that validation studies are time-consuming and costly, newer methods are required to automate the validation process. On the other hand, given the relatively low-resolution characteristics of echocardiographic imaging (less demanding on codec technology), older and freely available codecs may represent an efficient solution.

Methodology

Methodology is of paramount importance in imaging validation studies. The methodology we used to construct the original uncompressed clips (Figure 2) assured maximum DV quality with which to compare compressed clips, putting emphasis on any potential image degradation caused by video compression and, thus, strengthening the analysis of the effects of compression on motion video. Further, because all information surrounding the image sector was eliminated from all test images, and no pixeling effect was produced by compression in the vast majority of the images, we assured a truly blind evaluation by the observers, who could not recognize the original uncompressed images, eliminating bias toward video compression. A relative strength of our study is the use of multiple experienced raters from different institutions, and a large number of data points. Another strength is the use of original digital imaging to obtain compressed video clips, bypassing proprietary or DICOM JPEG compression used to store video clips on magneto-optical disks.

Advantages of High-grade Compression

The use of long cineloops (>3 cycles) and of multiplane sweeps greatly facilitates routine diagnostic work and is of paramount importance to increase diagnostic accuracy during rhythm disturbances or complex morphology analysis (eg, congenital heart diseases, masses, mitral valve scallop analysis). Although it has been suggested that extensive studies with multiple cardiac cycles and high-resolution images may not be necessary for routine transthoracic echocardiography,[13,23,24] many cardiologists are more comfortable when interpreting studies that include 3 to 5 cycle video clips as opposed to 1-cycle video clips. Further, diagnosis in transesophageal echocardiography is highly dependent on long, multiplane sweeps. Routine use of MPEG-4 compression allows digital acquisition of an extensive amount of diagnostic information (not constrained by 1-cycle video loops) without compromising storage requirements, costs, and easy transfer of studies over both broadband and narrowband networks. For example, the dimensions of a complete echocardiographic examination may range between 10 and 15 MB using MPEG-4 compression and 3-cycle video clips for each view.

MPEG-4 has become a widespread standard for video compression and broadcasting over the Internet. This allows a standard CD or DVD player, or any computer platform (including palm-size personal computers) to play MPEG-4–compressed echocardiographic examinations. To date, hardware costs associated with MPEG-4 technology are minimal.

Study Limitations

Currently, MPEG-4 is not included in the DICOM 3.0 standard, implying that encoding must be obtained using frame grabbers and, thus, that image calibration is not included into the digital data, and that minor distortions in color and gray scale may occur.[2] Our study has demonstrated that, should these minor distortions occur, they probably have no significant clinical relevance. Furthermore, the calibration issue is probably counterbalanced by a significant reduction in hardware, software, and storage costs, of great significance for many echocardiography laboratories around the world. But, most importantly, MPEG-4 may open the way to widespread use of ubiquitous low-bandwidth lines for study transmission, therefore, making tele-echocardiography feasible irrespective of logistic or economic issues. The newer versions of MPEG-4 technology are under scrutiny and may be included in the DICOM standard in the near future. Further studies are needed to analyze the issue of the accuracy of measurements obtained on still frames obtained from MPEG-4 encoded video clips.

Human assessment is considered an optimal method to evaluate and compare motion video sequences. However, evaluation variability exists, which reduces the accuracy to compare subtle differences in imaging. We assessed this accuracy threshold with intraobserver variability analysis, which suggested that, on average, the observers could not discriminate between neighboring scores on the 5-point scale. This limitation was not considered significant for the purposes of the study. Although a quantitative analysis on pixel values in a given video frame between uncompressed and compressed images would have provided more objective and accurate results, we thought this latter analysis to be beyond the scope of our study, which aimed at analyzing motion video imaging in a clinical setting.

Conclusion

Our study demonstrates that the use of MPEG-4 video compression compares favorably with uncompressed echocardiographic images even at high compression grades, supporting the use of MPEG-4 algorithms to greatly reduce digital echocardiographic motion image size for both archiving and transmission (tele-echocardiography) purposes.

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