Low Cost Telesonography Model for DDH Exam

Dobrivoje Martinov, Zoran Ignjatov, Dragan Markovic

Abstract— Telemedicine holds important place and has wider use in health care practice and improvement of health organization, above all providing the opportunity for standard and innovative procedures to combine. Tremendous increase in Internet bandwidth enabled a true revolution in image transmission and enabled easy remote viewing of the static images. However, transmission of real time video streams such as in ultrasound has been underreported.

Here, we tested feasibility of the low-cost teleultrasound system for developmental dysplasia of the hip (DDH) screening and diagnostic values of the transmitted images and video data in real time.

Sending of data was accomplished with a software package specifically designed for teleultrasound transmission through limited Internet bandwidth.

Using Remote Ultrasound (RU) software in conjunction with a hardware setup and low bandwidth Internet link, we performed sonographic DDH screening exams in real time. In addition to continuous monitoring of the exam via video stream, RU enables remotely controlled recording and selection of still images on a sending and a receiving computer.

Qualitative analysis of 50 transmitted ultrasound images and all video streaming during each exam, were performed.

Teleultrasound screening through the Internet connection of low transmission power with the software application, provides ultrasound image and video stream, which is the base for further clinical investigation and clinical application of this model.

Index Term— teleultrasound, low cost, developmental dysplasia of the hip, medical diagnosis, imaging transmission, image analysis, video reviews, medical imaging, medical treatment

INTRODUCTION

Rapid growth and development of information systems and communications that fueled development of telemedicine enabled a constant increase in quality of telemedical service, primarily exemplified in improved telemedicine interfaces and increased speed of transmissions. Worldwide availability of Internet infrastructure has opened door for exchange of medical information on a global level [1] [2].

Transmission of still images and cross-sectional data has been widely used in both developed and developing world [3]. However, we focused on utilization of ultrasound and transmission of ultrasound image and video data. Reasons for this are twofold, the unique features of ultrasound and technological challenge of ultrasound data transmission.

Low-cost, availability of portable ultrasound units, safety features all enable its easy integration into both primary care and secondary care settings in developed as well as in the developing world. Two consequences, immensely important for the medical field are the educational potential and opportunities for public service [4].

Here, we tested feasibility of the low-cost teleultrasound system for DDH exam and clinical application of this model.

MATERIAL AND METHODS

All imaging was done with Sonosite 180 (Sonosite Inc.), a portable ultrasound unit donated by Dartmouth-Hitchcock Medical Center, and Shimadzu SDU-450 ultrasound unit in General Hospital “Djordje Joanovic”, Zrenjanin, Serbia.

Variety of computer configurations tested for transmission of ultrasound images included 2 to 3 GHz Pentium 3 and Pentium 4 processors, operative memory from 256 MB to 3GB and multiple graphics cards. All computer configurations were running Windows XP OS.

Ultrasound image was transmitted to the computer via a Pinnacle PCTV Analog USB TV tuner video capture card.

RU Software application, developed at Dartmouth [5] [6] was used for transmission of ultrasound image via low bandwidth Internet links between Serbia and USA. The software is based on open source libraries and standard video conferencing protocols available in Microsoft Research Group [7] and operates under Windows XP and .NET environment. This unique application enabled us to use ultrasound in the settings of limited resources.

More specifically, the software enables:
1) direct monitoring of ultrasound exam in real time via teleconferencing module that in addition to audio link transmits ultrasound video stream,
2) recording and review of still ultrasound images, similar to functions available on ultrasound machine,
3) remote saving of ultrasound imaging – a function that saves images on local and remote computer and thus enables direct comparison of images by personnel on both locations,
4) ability to add additional text to images.

Like all other tele-conferencing software application, RU uses range of CODECs for lossy compression of video and still images.

In the initial phase of this project, we tested software and hardware configuration in three settings:
1) Local area network (LAN) with connection speed of UL/DL: 100 Mbps,
2) Metropolitan Area Network (MAN) within one Internet service provider with connection speed UL/DL: 2000/2000 Kbps,
3) Wide Area Network (WAN) with connection speed UL/DL: 512/64 Kbps.

With final hardware configuration, 25 examined babies, where age from 2 to 7 months. All diagnostic examinations were performed in General hospital “Djordje Joanovic” Zrenjanin, using linear probe (7.5 MHz) in real time by the trained sonographer.

Save function (Save Still) of the NetAVSender application was used to record the still images while the ultrasound probe was moved or when the images were “frozen” on the ultrasound machines.

Every time Save function is used, it records a dataset of images on the sender’s and receiver’s computer, which are exchanged and used for image analysis.

Complete video stream teleultrasound DDH examination was followed up on RU by the sonographer in America.

Quality of the recorded ultrasound images was variable, but there was no attempt made to improve the quality by rescanning, refreezing or re-recording the image sets. Quality of the images was assessed according to the presence or absence of major topographic points described by Graf [8] [9].

Qualitative Analysis was performed on 50 remotely recorded ultrasound image sets, obtained in freeze mode. The same number of video recordings of complete teleultrasound examinations in real time on Remote Ultrasound (receiver) was monitored by the sonographer in America.

Qualitative analysis of image sets: An image database was created by 50 transmitted images. Five experienced clinicians from Children’s Hospital in Novi Sad, Serbia assessed the quality of transmitted saved images by grading them from 1 to 5, where 1 was lowest and 5 was the highest grade.

Reviewers graded transmitted images that were offered in uniform form. Grading was based on the presence or absence of anatomic landmarks (points and lines) used for morphologic classification of sonographic images according to Graf.

Morphologic determination of the bony and cartilaginous angles of the acetabular roof:

- All landmarks are visible – grade 5
- All landmarks are barely visible, Important landmarks are clearly visible – grade 4
- Important landmarks are visible – grade 3
- Only some important landmarks are visible – grade 2
- Important landmarks are not visible – grade 1

The images graded with the grade 1, present clinically bad results (can’t establish the diagnosis), graded with 2, present need to repeat the examination, and with grade 3, 4 and 5, present useful clinical results (can establish the diagnosis).

Qualitative analysis of video streaming:

Another reviewer graded transmitted real time video stream of DDH examination. Grading was based on diagnostic usefulness to confirm or exclude the DDH: can establish the diagnosis, need to repeat the examination, can’t establish the diagnosis.

RESULTS

Final hardware platform used in all teleultrasound exams was: notebook MSI EX610X-082EU, with AMD Athlon64x2 TK55 chip, DDRII 3GB, ATI HD2400, running MS Windows XP with Service Pack 2.

Ultrasound (US) image in real time was transmitted in environment of Internet Upload of 250 Kbps and frame rate of 5 frames per second through WMV9 coder.

The software enables:

1. Direct monitoring of ultrasound examination in real time via teleconferencing module that in addition to audio link transmits ultrasound video stream.
2. Recording and review of still ultrasound images, similar to functions available on ultrasound machine.
3. Remote saving of ultrasound imaging – a function that saves images on local and remote computer and thus enables direct comparison of images by personnel on both locations.
4. Ability to add additional text to images.

Figure 2 depicts RU interface on sender’s and receiver’s side, respectively. The usual teleultrasound session was initiated by the team in Serbia by inserting IP address of the receiver’s computer into an IP address bar and pressing Send button (see Figure 2). After about 2 second, the video stream appears on the receiver’s computer and the examination is started.
Ultrasound examination of both hips revealed normal findings in all 25 examined babies.

Save function (Save Still) of the NetAVSender application was used to record the still images while the ultrasound probe was moved or when the images were „frozen“ on the ultrasound machines.

Every time Save function is used, it records a dataset of images on sender's and receiver's computers. Complete datasets on sender's and receiver's computer were exchanged and used for image analysis (Fig. 3).

Five experienced sonographers reviewed transmitted images (Table I). In reviewers I and V most frequent grade was 3, reviewer II did not give neither one best grade, reviewer III gave mostly bad grades and reviewer IV mostly good grades (Fig. 4).

From the total of 250 transmitted images (Figure 4), 28 images (11.20%) were graded with 1, 68 (27.20%) were graded with 2, 94 (37.60%) were graded with 3, 45 (18%) were graded with 4 and 15 images (6%) were graded with grade 5 (Fig. 5).
Fig. 3. Original sonogram (a) and transmitted sonogram (b)

**Table I**

**SUBJECTIVE IMAGE ASSESSMENT (GRADING 1-5, REVIEWER'S I-V))**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Reviewer I (I)</th>
<th>Reviewer II (II)</th>
<th>Reviewer III (III)</th>
<th>Reviewer IV (IV)</th>
<th>Reviewer V (V)</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 (4%)</td>
<td>1 (2%)</td>
<td>18 (36%)</td>
<td>4 (8%)</td>
<td>3 (6%)</td>
<td>28 (11.20%)</td>
</tr>
<tr>
<td>2</td>
<td>13 (26%)</td>
<td>20 (40%)</td>
<td>23 (46%)</td>
<td>7 (14%)</td>
<td>5 (10%)</td>
<td>68 (27.20%)</td>
</tr>
<tr>
<td>3</td>
<td>27 (54%)</td>
<td>18 (36%)</td>
<td>8 (16%)</td>
<td>12 (24%)</td>
<td>29 (58%)</td>
<td>94 (37.60%)</td>
</tr>
<tr>
<td>4</td>
<td>8 (16%)</td>
<td>11 (22%)</td>
<td>1 (2%)</td>
<td>13 (26%)</td>
<td>12 (24%)</td>
<td>45 (18%)</td>
</tr>
<tr>
<td>5</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>14 (28%)</td>
<td>1 (2%)</td>
<td>15 (6%)</td>
</tr>
<tr>
<td>Σ</td>
<td>50 (20%)</td>
<td>50 (20%)</td>
<td>50 (20%)</td>
<td>50 (20%)</td>
<td>50 (20%)</td>
<td>250 (100%)</td>
</tr>
</tbody>
</table>

Fig. 4. 250 images sampled from 50 DDH teleultrasound examination graded from 1 to 5 according to a five different reviewers
We selected the all transmitted images with grad 1 as bad results (can't establish the correct diagnosis), with grade 2, need to repeat the examination, and grade 3, 4, 5 as good results (can establish the correct diagnosis). Respectively, another reviewer selected the video stream according to clinical usefulness on the same manner.

Diagnosis can be established on the base of 154 (61.60%) images, while for the rest of 96 images (38.40%) examination need to be repeated (Table II).

Video streaming is clinically useful in 92%, and examination need to be repeated in 8% (Fig. 6).

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Can establish the correct diagnosis</th>
<th>Need to repeat the examination</th>
<th>Cant establish the correct diagnosis</th>
<th>∑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image</td>
<td>154 (61.6%)</td>
<td>68 (27.2%)</td>
<td>28 (11.2%)</td>
<td>250 (100%)</td>
</tr>
<tr>
<td>Video</td>
<td>46 (92%)</td>
<td>4 (8%)</td>
<td>-</td>
<td>50 (100%)</td>
</tr>
</tbody>
</table>
DISCUSSION

Tremendous increase in internet bandwidth enabled a true revolution in image transmission and easy remote viewing of the static images [10] [4]. However, transmission of real-time video streams such as in ultrasound or in fluoroscopy has been underreported [11]. „Since 2003 MPEG-2 video compression is approved in DICOM standard for videos.“ [12]

Major technical advances and impressive growth in streaming technology for live transmission of multimedia contents [13] [14], give us to apply this possibility to clinical practice.

Prior reports reveal that teleultrasound examination with limited resources could be clinically useful [5] [6] [15]. Ultrasound is a powerful tool in diagnosis of DDH [16] [17]. Here, we presented a model that utilizes teleultrasound in the settings of limited resources. To the best of our knowledge, this is the first report of the teleultrasound model used for DDH screening. In addition to continuous monitoring of the exam via video stream, RU offers remotely controlled recording and selection of still images on the sending and the receiving computer. Model that we are developing, gives us an opportunity to apply ultrasound screening to a wider population (high risk newborns or all newborns) and also to use this model in urgent situations, in regions that lack trained ultrasonographers or developed medical infrastructure.

In this model, portable Sonosite 180 ultrasound device offered adequate image quality that made teleultrasound applicable to DDH screening.

During the testing, it was ascertained that hardware characteristics significantly affect the quality work of software and that it is important to provide adequate speed values of processor for its successful use, the size of RAM memory and graphic card, which is essential for sender (the computer which send US image on distance).

Software solution used for teleultrasound screening showed good characteristics for US image transmission in real time in environment of Internet Upload of 250 Kbps and frame rate of 5 frames per second through WMV9 coder.

Set of 50 U.S. transmitted images, were given to the assessment, under the same conditions, according to uniform criteria, individually and independently, to five colleagues that previously were not in any way referred to this research.

The evaluation of all 250 US images shows that grade 1 was presented in 28 (11.20%) images, grade 2 in 68 images (27.20%), grade 3 in 94 (37.60%), grade 4 in 45 (18%) and grade 5 in 15 images (6%).

By analyzing assessment of each examiner individually, it was noticed that the examiner III gives low grades and the examiner IV high scores. The other three examiners gave average high scores equally.

Ultrasoundgraphy is a subjective method and may be an explanation for the observed differences in the evaluation of the same set of images by the different examiners.

For qualitative analysis of images set there were five reviewers included. Because of technical difficultness to organize monitoring of video stream in (real) time of DDH examination there was one reviewer, for video stream analysis.

In this research there was no problem in video streaming like freezing behavior [6] or disconnection.

In the clinical practice, teleultrasound video stream examination of infant hip, gave much better results. The correct diagnosis can be established in 92% via real time video stream, respectively the correct diagnosis was establish in 62% via still images.

Commonly, US device has the ability to store a set of US images, and after review, searching can choose high quality and clinically useful US images, which requires, with time, sometimes repeating views to store adequate US images. More comfortable way is to monitor the full video review, where characteristics are easily observed as well as important point and lines for the diagnosis. Possible ambiguities and concerns are, during the examination, easily solved by moving the probe in a standard way to display the desired lines and points.

The possibility of transfer of video streams with limited resources significantly simplifies and raises the quality of US examinations in the distance because it does not require expensive equipment. Visibility of essential lines and points is easier, compared to diagnosis based on US images.

DDH ultrasound screening exam is unique in the sense that there is limited cooperation with the patient. In other words, it is hard to limit motion of the baby and hold probe still in sonographer’s hand. Sometime is hard to take correct images at once. Also, due to high degree of motion, lossy video stream compression is increased and the transmitted stream is lower in quality. To test image quality during transmission, we included from all exams, even those in which the movement of the baby and the probe was considerably high.

During ultrasound examination, Lossy compression by the US software is variable and depends on the quality of internet connection and of the size of incoming video stream. Although this software does not transmit video stream according to DICOM standard [18], it provides adequate real time video image. By adjusting the transmission in FFDSShow to values of 250 kbps, it provides undisturbed US screening in real time, which fits in low bandwidth.

CONCLUSION

Transmission of ultrasound data was accomplished with Remote Ultrasound, a software package specifically designed for teleultrasound examinations through Internet connections of limited bandwidth. Using Remote Ultrasound software application, in conjunction with a hardware setup and low bandwidth Internet link, we performed sonographic DDH examinations in real time. In addition to continuous monitoring of the exam via video stream, RU offers remotely controlled recording and selection of still images on the sending and the receiving computer.

During the testing, it was ascertained that hardware characteristics significantly affect the quality work of software and that it is important to provide adequate speed values of processor for its successful use, the size of RAM memory and graphic card, which is essential for sender (the computer which send US image on distance).
Software solution used for teleultrasound screening showed good characteristics for US image transmission in real time in environment of Internet Upload of 250 Kbps and frame rate of 5 frames per second through WMV9 coder.

Video stream gives much better results in clinical application then transmitted still images.

Teleultrasound screening through the Internet connection of low transmission power with the software application, provides ultrasound image and video stream, which is the base for further clinical investigation and clinical application of this model.

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