Pilot clinical evaluation of prototype system for visually reporting the results of ultrasound examination

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ABSTRACT

A dedicated optic-mechanical device, attachable to an ultrasound scanner, has been developed that allows visual documenting of ultrasound examination by recording multiple gray-scale images, i.e. ultrasound tomography (UST), to be performed routinely and at low cost. The device is operated by one hand without interrupting the examination. Each page of UST report is composed by deliberate positioning multiple images within the 2x4 framework and recorded on a 35-mm microfilm. If necessary, graphic reconstructions were composed from standard graphic components and interposed between the original images on the same frame. UST report is communicated to a patient and/or a referring doctor on a compact reflective hardcopy. Trial-and-error search for optimal number of images that constitute adequate UST document resulted in plateau of average 30±1.8 images per patient visit. Practice of UST is well accepted by local medical community and by patients, and the first year since its introduction yielded two-fold growth of referral to Ultrasound Studio. Low-cost optic-mechanical UST system could create locally culture of reporting ultrasound examination in images rather than verbally, and facilitate for further introduction of more advanced digital systems.

Keywords: sonography, image storage, image interpretation

1. INTRODUCTION

Ultrasound (US) is one of the most widely used medical imaging modalities worldwide[1]. Techniques of ultrasound images recording are numerous[2,3] (multiformat camera, film camera, videothermoprinter, videorecording, digital storage). It is possible to view the 3D model of an organ within the body of a patient[4]. The systems for reporting the results of ultrasound examination are not uniform, although the inclusion of images into a report is advisable[5]. Modern digital systems make possible retrieval of large volumes of visual information that obtained during ultrasound scanning of the body, but the question still remains, how this information should be presented to the users[6,7] (operator of ultrasound scanner, radiologist, referring doctor, patient).

In this paper we do not include our previous sixteen-year experience of documenting ultrasound examination using single-image records (photography), and linear sequences of such images (thermoprinter and videotaperecorder). Meanwhile, this was in fact “stage zero” of the present study and the dissatisfaction with those techniques was a stimulus to look for cheap technique of recording ultrasound cross-sectional examination on multiple-image hardcopy. In last years, one of us (A.B.A.), running a for-fee open-access ultrasound counseling center (Ultrasound Studio), and must especially regard legal, professional and ethical problems, related to reporting the ultrasound examination.

Taking into account this practical experience and theoretical research on telemedical application of artificial intelligence[8] methods, we formulate the requirements to the reporting system as follows. A clinically-oriented verbal part (preferably, established diagnosis or suspicion) should be accompanied by a visual part; this later should be “browsable”, so as to be read by professional in seconds; be original, i.e. containing “rough” images as obtained by an ultrasound scanner. It also should be persuasive. And, also it should permit several levels of understanding (trained radiologist, general practitioner, technician, patient).

The purpose of the present study is to evaluate: 1) the number of images that is necessary to record during the US exam to produce the document of sufficient information volume, and 2) if the format of US visual report should include additional information except from the original images.

2. MATERIALS AND METHODS

Ultrasound Studio provides ultrasound services for the patients counseled by its own practitioners (internal medicine and pediatrics), as well as for patients referred by other medical practices (cardiology, andrology, gynecology) and state clinics (primarily oncology). With this regard, some ultrasound examinations could be qualified as “targeted study” (including referrals from other ultrasound laboratories for confirmation and/or visual documentation of their findings). Other examinations were “search” and “work-up” examinations. The distribution of patients and studies by the number of organs/locations studied during a single visit is presented in Table 1 and in Figure 1.

Table 1. Organs/locations studied at ultrasound examination and respective frequency of their inclusion in examination

Organ/location	%
Kidney	60
Liver and Gallbladder	50
Uterus and Ovary	30
Pancreas	25
Prostate and Seminal Vesicles	25
Heart	20
Thyroid gland	15
Other organs/locations	10

Methodology of the present study is based on the approach as follows. New technology of visually documenting the study was incorporated into the routine workflow of for-fee counseling, and the evolution was assessed qualitatively by the number of images recorded at each examination. A dedicated optic-mechanical device was designed for low-cost recording of multiple US images on a microfilm. The visual report was composed by the sonologist during US examination by positioning selected images on a microfilm in one of selected formats (4x2, 3x3 or 4x4 images per frame). If necessary, graphic reconstructions were composed from standard graphic components and interposed between the original images on the same frame. Reflective gray-scale copies were used to communicate the results of US examinations to a referring physician and for analysis. 210 consecutive US examinations have been documented. At second-look analysis the sonologist scored the US visual report as "adequate" or "subadequate". The referring physicians scored the report as "easy to understand" or "difficult to understand".

3. RESULTS

The device is operated by one hand without interrupting the examination. Visual report documenting the ultrasound examination is easily composed, after gaining experience, within the routine 30-minute scanning session, and technical mistakes are encountered not frequently.

An example of the format, finally chosen for the page of the visual ultrasound report, is shown in Figure 2. Evolution of practice of visual documentation for ultrasound examination since the system was introduced is presented in Figure 3.

Figure 4 shows the number of images, recorded for documentation of a particular organ. More or less distinguishable two-peak distribution is characteristic for all organs. The first peak corresponds to routine documenting, and the second peak corresponds to extensive documenting (complicated anatomy and/or pathology, poor visualization – noisy image, exclusion of suspected cancer, assessment of disease stage and operability).

By the sonologist's estimate, 146 (73%) reports were scored as "adequate", and 54 (27%) reports as "subadequate". "Adequate" reports contained from 8 to 72 images (moda = 32), and "subadequate" contained from 4 to 16 images (moda = 4). When diagnostic information lies close to the noise level, 3 to 8 images of practically the same position/orientation were recorded to provide "statistically sufficient evidence". By the physician's and/or sonologist's estimate, 72 (36%) reports were in need of explaining graphic reconstruction. Such explaining reconstructions were included in 56 reports. 48 (85%) of those graphically explained reports were assessed as "easy to understand" and 8 (15%) as "difficult to understand". In comparison with 144 reports that do not contain reconstructed images, 70 (49%) were assessed as "easy to understand" and 74 (51%) as "difficult to understand".

Practice of UST is well accepted by local medical community and by patients, and the first year since its introduction yielded two-fold growth of referral to Ultrasound Studio (Figure 5).

4. DISCUSSION

Ultrasound is known to be operator-dependent, and sometimes this disadvantage shifts patients and physicians toward more expensive computed tomography (CT) or magnetic resonance imaging (MRI). Wider and systematic use of visual documentation by recording multiple gray-scale images, a practice known for years, can improve confidence in US and create new markets for consumables and accessories.

Ultrasound tomography (UST) is understood here as practice of (and technology for) routine systematic documentation of ultrasound examination by recording multiple images for consultation and clinical observation as well as for scientific, legal, and educational purposes. By analogy with practice established worldwide for CT and MRI, in UST during the examination of a patient, selected images are positioned on a document sheet in the special order, and optionally are combined with explanatory images (e.g. contour-enhanced), reconstruction, and reference anatomic schemes for representation in electronic form or as hardcopy. The number of scans (images) sufficient to give clear and adequate impression of studied anatomy and pathology was assessed in the present study experimentally. By the first estimate it is of between 8 to 64 per case per visit.

At UST sonologist is encouraged to think in stacks of images laid out on document sheet, rather than hunting for "best shot" while looking through pathology. Economy plays the key role in making the UST really everyday practice of communication with a referring doctor. Naturally, in different economic environments the level of "affordability" can vary. Correspondingly, the technology of UST can vary, e.g. digital versus non-digital options. In present Ukrainian project on UST the dedicated optic-mechanical device is used for documenting on microfilms. This enables us to archive standard set of two 4 x 4 images sheets at price of 0.2 USD and to produce hardcopy at price of 1 USD in consumables. Promotion of UST will be on making physicians and radiologists aware on availability of technique, stimulating use of US-tomograms in their routine practice, and giving them the benefits of being in touch with ultrasound without purchasing the equipment. Low-cost optic-mechanical UST system could create locally culture of reporting ultrasound examination with images rather than verbally and further facilitate for introduction of more advanced digital systems.

Graphic reconstruction of topology is very desirable in visually reporting results of US examination. Multiple cross/sectional images are better understood and anatomically attributed if organized around the graphic reconstruction or anatomic reference scheme. In quick reporting to a referring doctor, in teleradiology or in search systems, reconstruction could be sufficient and not accompanied by original gray-scale images. In that case we do not need to transfer large amount of photographic images over a network. Topology graph's reconstruction 'per se' could be sufficient. Such a reconstruction that encoded with one of the vector formats or XML-based language for graphical information[8]. Moreover, XML format allows to store text comments for each figure and use ones for purposes of analysis, search systems, indexing in databases and so on.

Such methodology of US documentation allows effective access, storing and processing reports in computer systems. At the present time, we study the possibility of developing and building automatic computer system for document management in Ultrasound Studio. One of the open questions is automation of the graphic reconstruction process. Theoretically, the system should choose more relevant frames of the film and build geometric primitives by itself. At the first stage, it will be nice if the system helps to make graphical restoration with the set of basic figures and using principal rules and database of previous cases. The core of the system could be a classifier[10] that uses some characteristics of origin images to produce relevant graphic figure. Figure 6 illustrates main components of such system and interaction between them. Expert assumptions are selection of key frames and correction of graphical remarks that were made by expert system. When knowledge base of the system has the necessary amount of cases to produce predictions with satisfactory level, use of expert will be significantly decreased.

Thus, implementation of US visual report in automatic computer system can improve efficiency of US exam and propose new facilities for medical personal and patients. Use of modern technologies for representation graphic reconstruction allows to distribute and represent US reports effectively and make them easy for understanding to wide range of people.

In order to introduce the practice of visual documenting in developing countries, the ultrasound center using low-cost documenting system will create a network of users and culture of reporting ultrasound examination visually rather than verbally. It could be speculated, that visual display (or hardcopy) of multiple ultrasound images may be more required by medical practitioners, as ultrasound images become easily recognizable and accompanied by explaining images.

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APPENDIX A

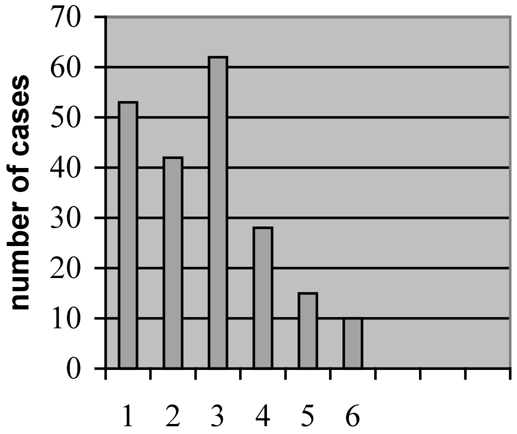

Figure 1. Distribution of ultrasound examinations by the number of studied organs

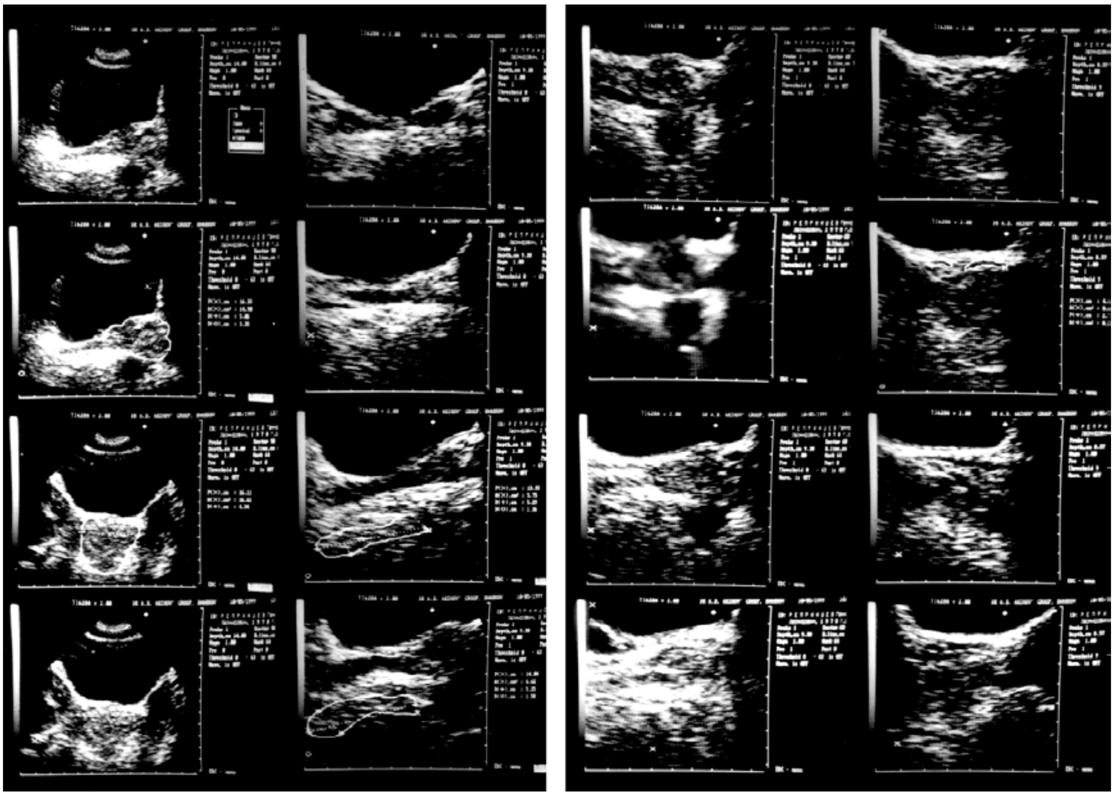

Figure 2. This format was, after trial and error, finally chosen as internal standard of Ultrasound Studio and affiliated practices and approved after discussions with Dr. E.Skornyakov who is a well-known specialist in treating male problems, such as insufficient sexual activity. He says that it is the only health problem of this particular 21-year-old patient.

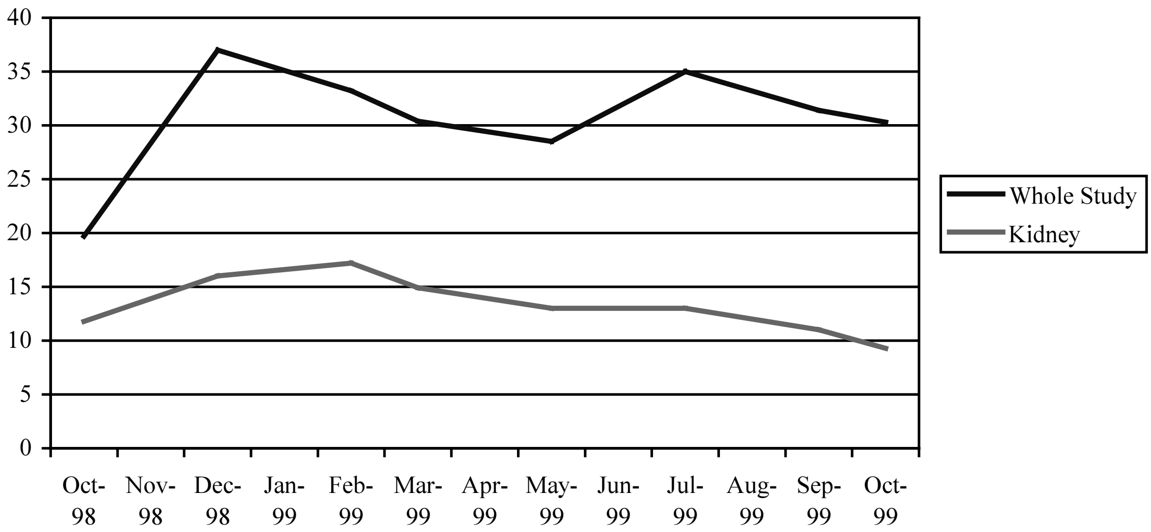

Figure 3. Dynamics of mean number of images recorded for visually reporting the ultrasound examination, after the introduction of system.

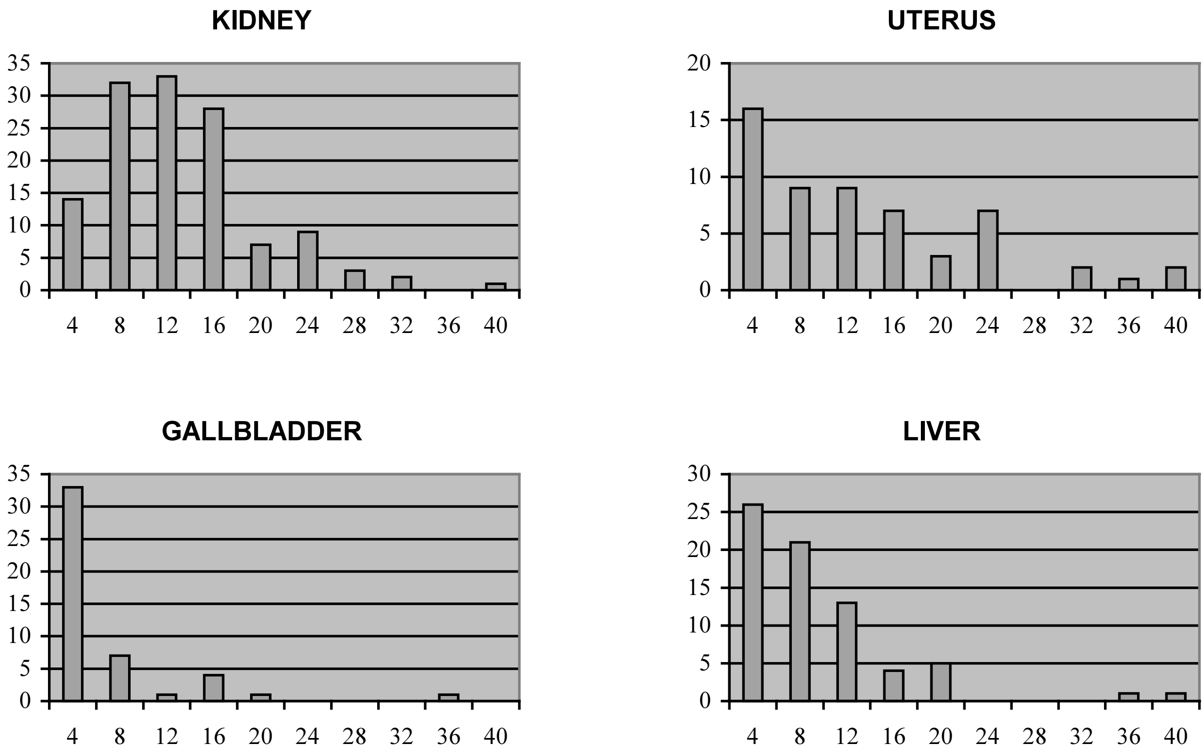

Figure 4. Patterns of frequencies of image-capacities used during the reporting anatomy and pathology of particular organs. Two-peak distribution is characteristic for all organs. First peak (low-volume reporting) corresponds to “routine cases”, and the second peak (extensive reporting) corresponds to difficult cases and/or poor image quality (e.g. in obese patients).

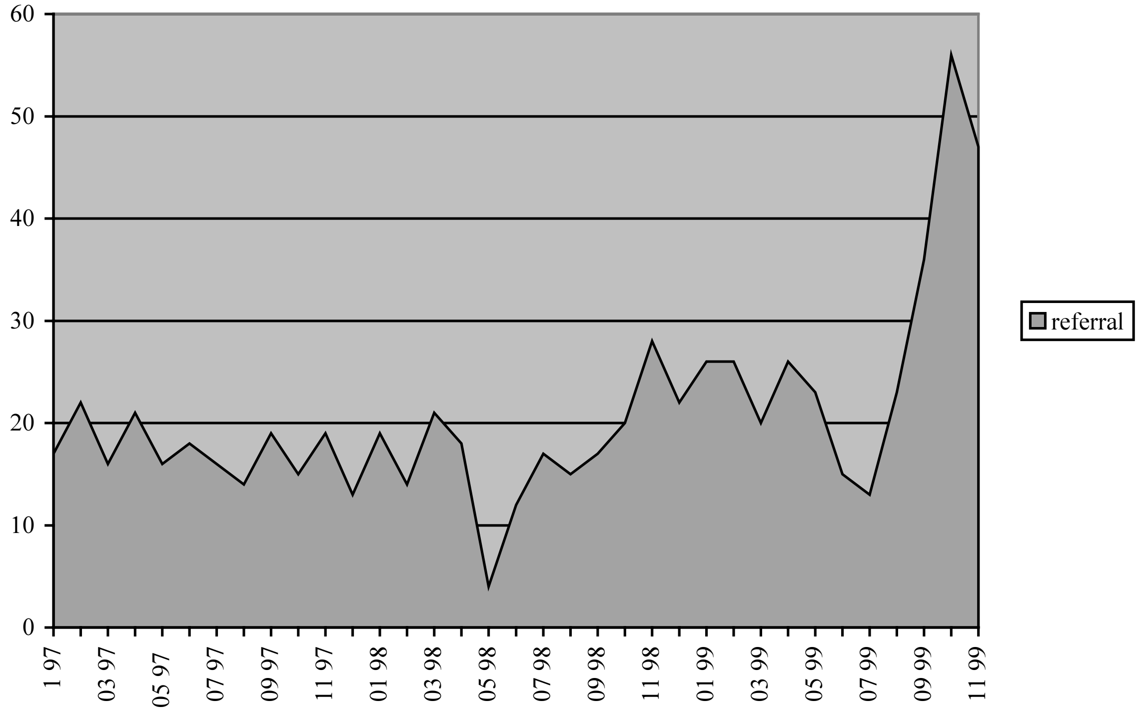

Figure 5. After the introduction of System for Visually reporting in October 1998, referral to Ultrasound Studio started to grow. What a wonder in declining economy of Ukraine!

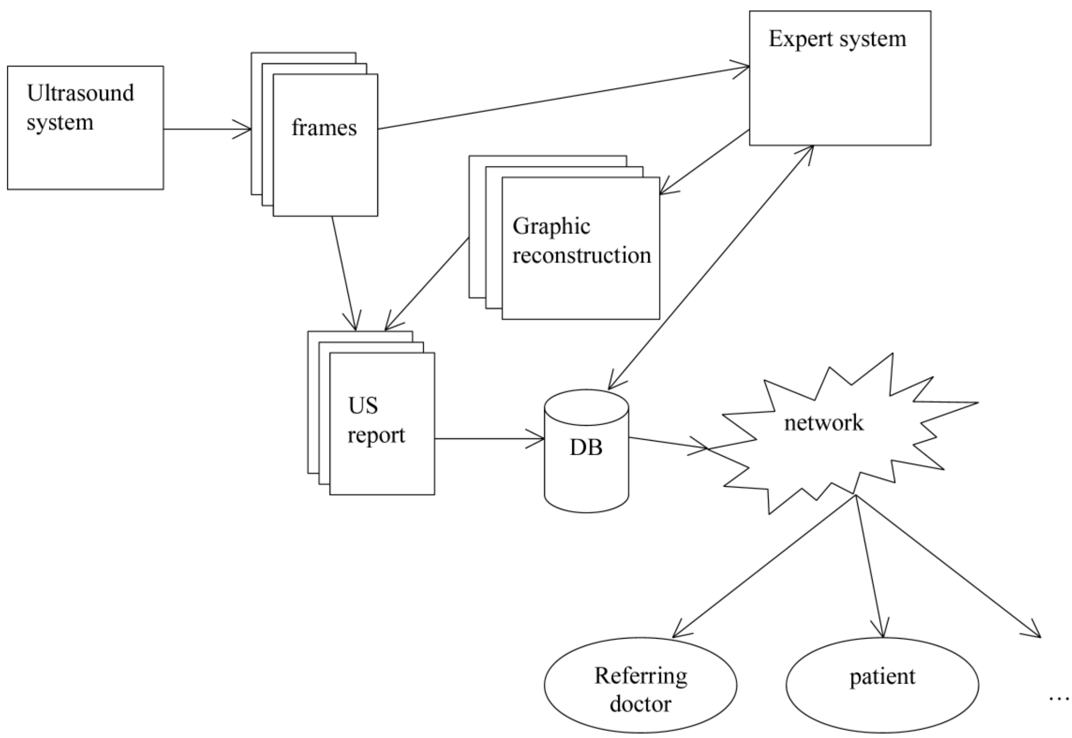

Figure 6. Logical scheme of the system for automatic graphic reconstruction.