

Visualization of the Ultrasonographical Scans in Critically Ill Neonates

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Abstract—Ultrasonographical scans and videos in the neonatal period of life are noninvasive possibilities to evaluate some critical information soon after delivery. The aim was to design and test of the innovative application of existing IT solution to new application domains with impact on improved skills in ultrasonography scan interpretation.

Keywords—neonate, ultrasound, visualisation

I. INTRODUCTION

This paper would like to present the process of data storage, evaluation and processing of the ultrasonographical digital pictures and videos in critically ill newborns. During the last years there are increased possibilities to scan different organs and systems bedside (3,4). In the same time, it is important to store data, reevaluate them and use them during the daily rounds and consultations. Early after delivery the ultrasonographical scans are more detailed, because of high extracellular body fluid content. The aims of the ultrasonographical investigation in the newborns are:

1. Discover life threatening conditions, abnormalities, morphologic abnormalities
2. Evaluate the circulation, discover morphologic abnormalities of the heart, evaluate and reevaluate the changes of the circulation based on the transition process of the lung and heart
3. Reevaluate the dynamic changes of the circulation after the established and selected therapeutic interventions
4. Discover and follow closely the changes in different organs
5. Educate nurses and physicians during the daily rounds
6. Project the findings to the big screen for the consultants and specialist during the consultations to decrease the need for reevaluation.

II. ULTRASOUND IN GENERAL

A. Powerfull ultrasound

Clinician performed ultrasound (CPU) is a powerful method for recognizing health and life-threatening conditions of patient, which is given to the hand of caring clinician in every day or night hour. Moreover, CPU often helps clinician to make a therapeutic decision in clinical cases, where there is not enough information gathered from other special examination techniques (invasive arterial blood pressure measurement, invasive pulmonary blood pressure, central venous blood pressure, CT, MRI, ...).

B. Image storage

The more clinicians taking care of the patient, the stronger urge to store images for further reevaluation/comparison occurs. Although there are tendentious to unite training in ultrasound, there is still quite a big amount of information bias in description of what is seen on ultrasound screen by different clinicians. This can be prevented by better training program (which is complicated, expensive and time-consuming way), or by storing the images for later

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inspection/comparison to the up to date finding (which is easier, cheaper and more reliable way).

C. Ultrasound by clinician and technical description of the system.

The system consists of three major components:

1. HiVision Server – is the core part of the system. It is an all-time running service, which accepts and processes store requests from multiple USG devices or other DICOM – compatible devices. The server indexes processed data for faster searching and processing and stores them using local or remote relational database management system. It also publishes web-services in local network, which are used for searching and visualization of previously – stored data.
2. USG device (or other DICOM – compatible devices) are communicating with HiVision Server, communicating and storing data in DICOM format and requesting worklist information. Communication can be achieved by using wired local area network (fixed equipment) or secured wireless network (portable equipment)
3. HiVision Client is user-interface part of the whole system. After authentication and authorization, HiVision Client enables users to look for current and archived patient data, perform postprocessing (i.e. ex-post measurements and image adjustment), categorization, worklist management and other tasks. HiVision Client is available as Windows or Android application. Multiple clients can be connected to single HiVision Server (using published web-services) and share all the data.

Clinician performed ultrasound (or in our case neonatologist performed ultrasound) can be helpful in a great variety of indications and clinical situations. In this paper, we are going to describe three cases, where the storage and later inspection of ultrasound images was helpful in setting the diagnosis, monitoring the development of the finding and setting the prognosis.

III. ULTRASOUND OF THE BRAIN

Neurosonography is a critical part of the care of the sick newborn especially in extremely low birthweight newborns (ELBWN). Sonography is superior to other modalities in imaging of the brain because it can be performed at the bedside, is easily reproducible, and does not require ionizing radiation or sedation. Intraventricular hemorrhage (IVH) in preterm neonates is a devastating consequence of prematurity that has both perinatal and postnatal antecedents [1]. Knowing the timing of IVH is a prerequisite for identifying its antecedents and subsequently applying preventive measures [2,3]. Studies before and after the widespread use of antenatal steroid and surfactant therapy have shown that IVH may occur as early as the 1st min. This observation suggests that IVH may occur in utero, intrapartum or during the early postnatal period [4,5,6]. A large body of evidence has shown that a considerable number of IVH cases occur during the first hours of life [7,8,9,10]. A high percentage of IVH is clinically silent [1,3]. Thus, there is universal consensus that all preterm neonates born at <30 weeks gestation or a birth weight of <1500 g should have a routine screening. Dynamic changes of IVH are shown on Fig.1.

IV. ULTRASOUND OF THE HEART

The role of echocardiography in the neonatal intensive care unit (NICU) has changed over the past few years. Previously, nearly all echocardiography studies in the NICU were performed by pediatric cardiologists to diagnose or monitor congenital heart disease and to screen for patent ductus arteriosus (PDA). More recently neonatologists become interested in the echocardiography assessment of hemodynamic instability in infants.

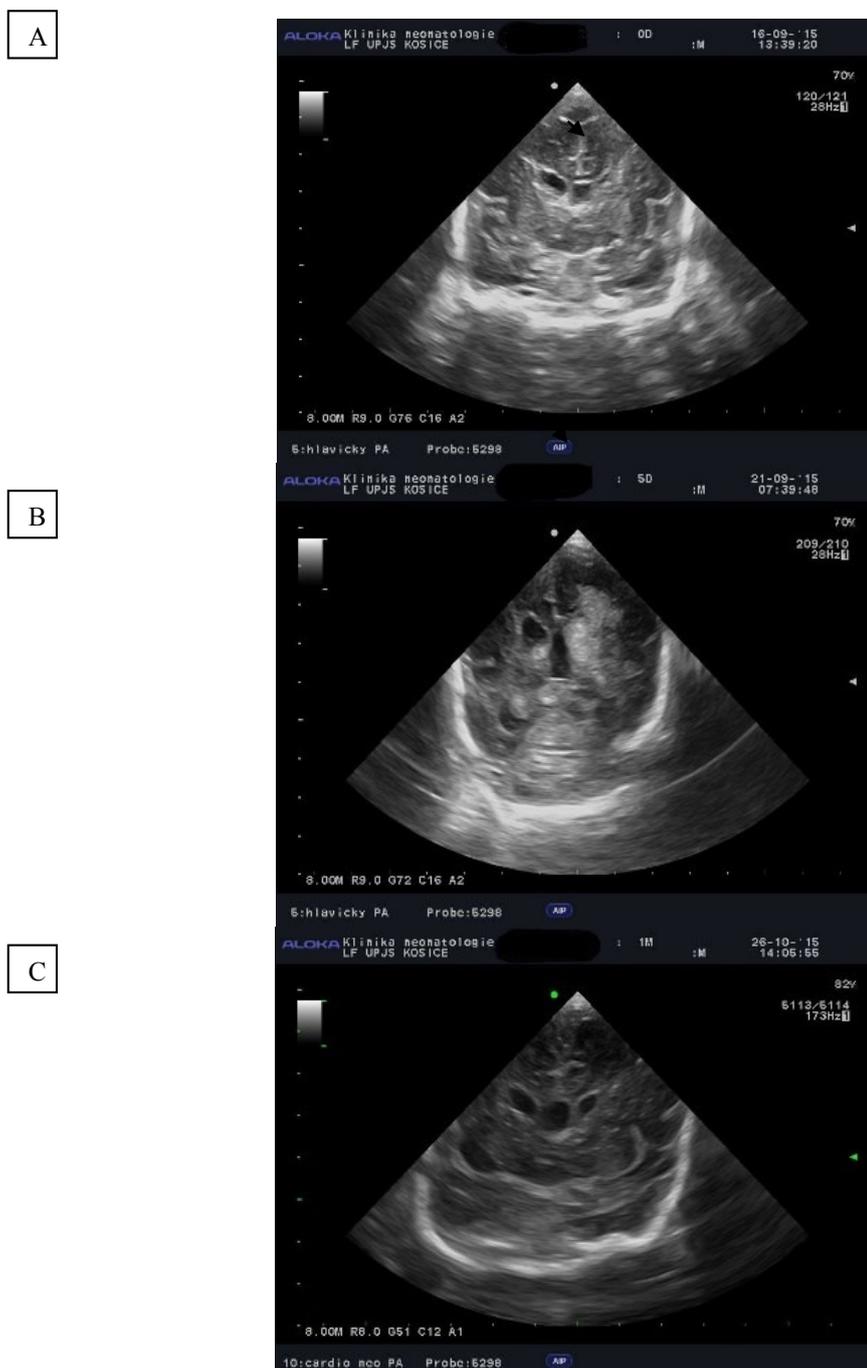


Fig. 1. Morphologic changes of the brain of the ELBWN. *Ultrasound of the brain soon after delivery (A), after the severe intracranial hemorrhage in age of 3 days; black narrow (B) and the control after the healing of the lesion in age of 40 days (C).*

A. Assessment of PDA

Although essential for the normal fetal circulation, persistent ductal patency may have significant deleterious effects in preterm or ill term infants. PDAs are found in about half of babies born <29 weeks of gestation and/or weighing <800g [11,12]. Failure of ductal closure, coinciding with the normal postpartum fall in pulmonary vascular resistance, results in left-to-right ductal shunt. The consequences may include pulmonary overcirculation and/or systemic hypoperfusion, both of which may be associated with significant morbidity. Large PDA creates hemodynamic complications including renal insufficiency, necrotizing enterocolitis,

intraventricular hemorrhage, and myocardial ischemia. Correct timing of assessment may lead clinicians to initiate proper treatment, and complications of large PDA could be avoided. Dynamic changes during treatment of PDA are shown on Fig. 2.

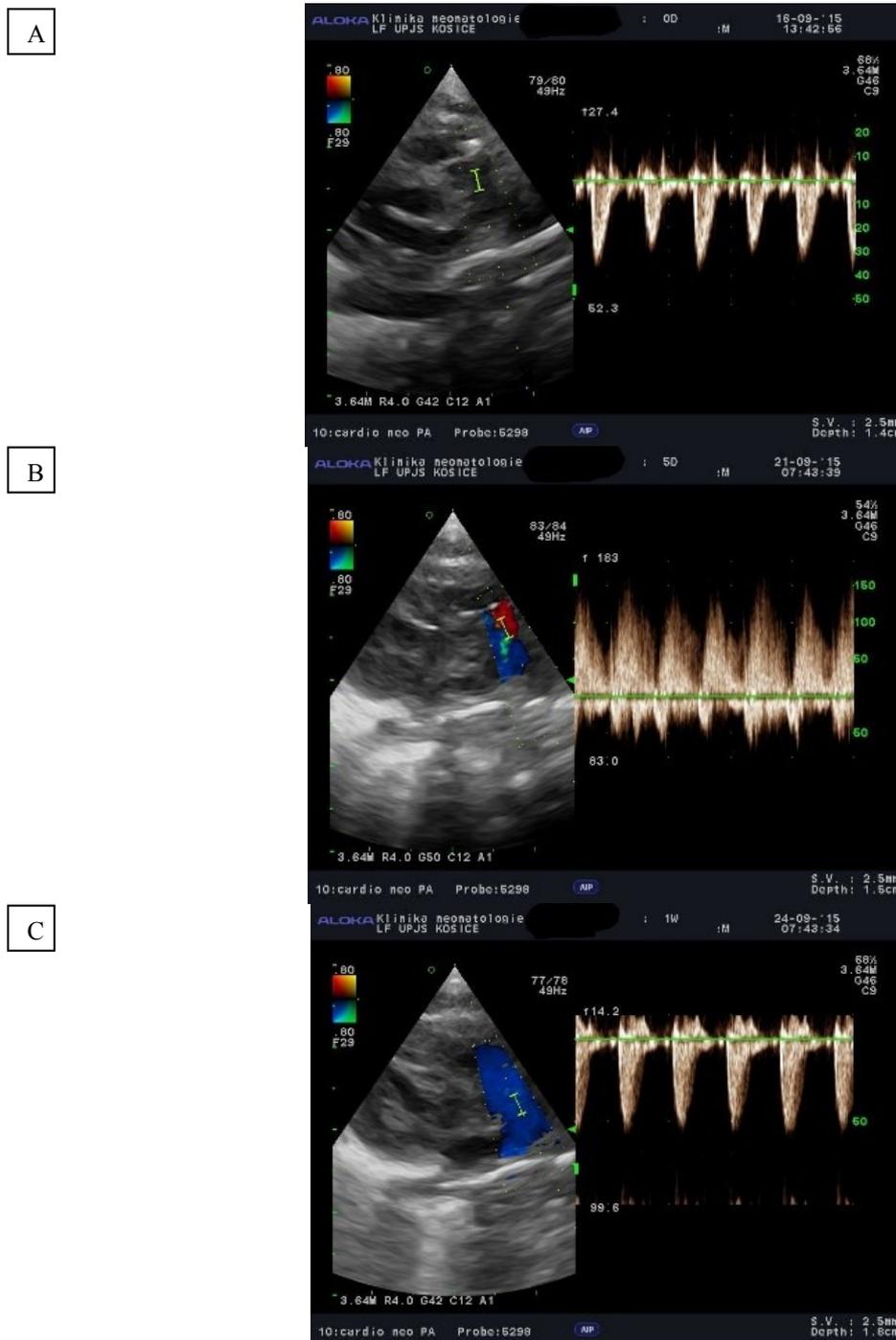


Fig. 2. Doppler flow measurements in the pulmonary artery of the ELBWN. *Soon after delivery (A) , signs of ductus arteriosus persistent in age of 5 days (B) and three days later after the treatment with ibuprofen (C).*

B. Assessment of heart contractility and changes of the cerebral blood flow curves measured by doppler velocimetry.

In severe cases of congenital nonimmune hydrops one time evaluation of the heart contractility, morphology and analysis of the cerebral blood flow measurements could discover

interactions between the heart rate, atrial flutter and changes of the cerebral blood flow curves [14]. This is the reason, why it is important to evaluate the brain and heart together with the changes of the circulation by one person, by neonatologists carrying about the complicated cases. The atrial flutter could be treated by cardioversion with the reevaluation of the cardiac rhythm not only with electrocardiogram, but also with the evaluation of the cerebral blood flow curves giving different view to the pathophysiology of the disease. Fig. 3,4.

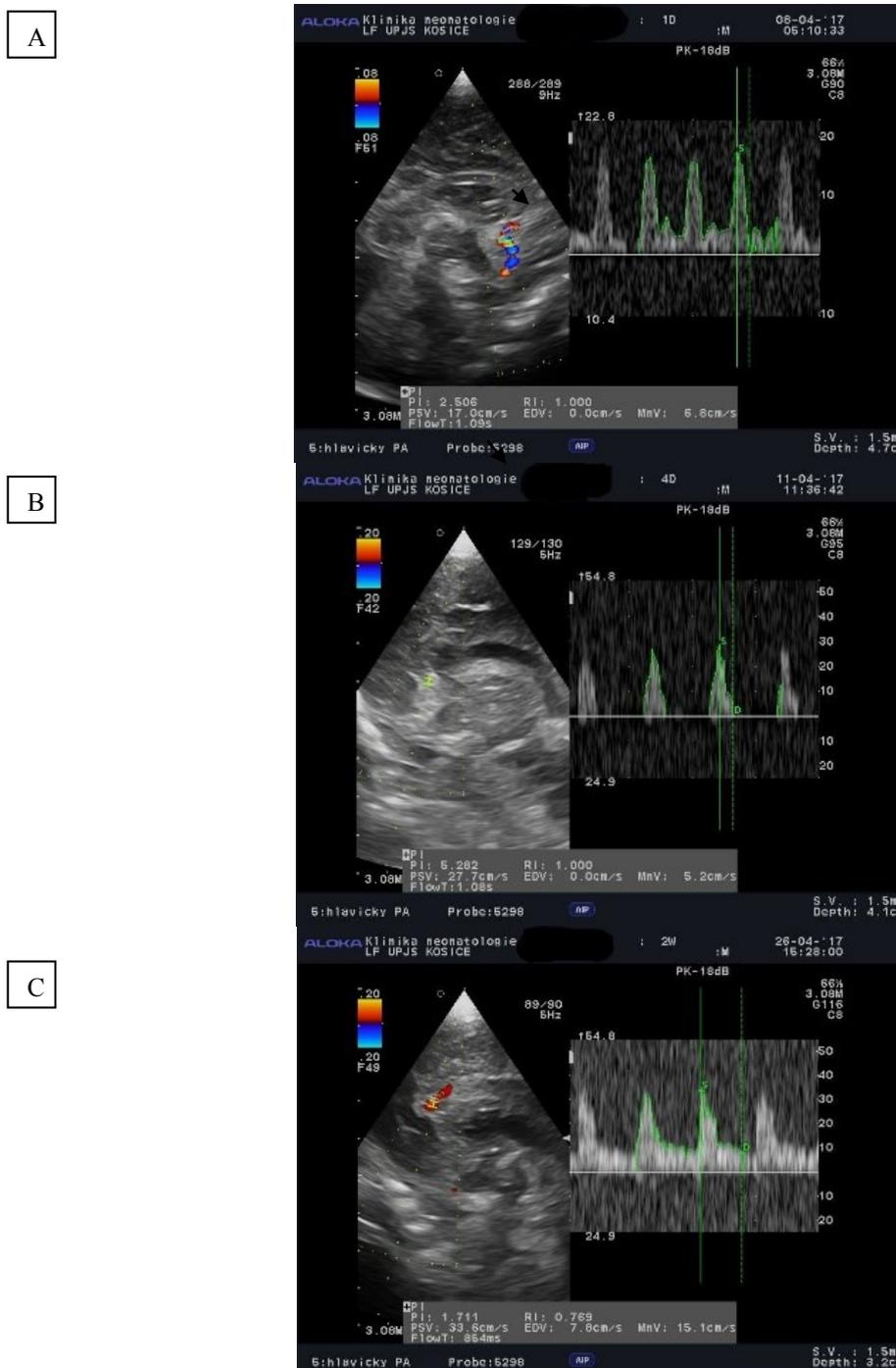


Fig. 3. Changes of the doppler flow curves in the brain.

Changes of the doppler flow velocimetry discovering atrial flutter visible in the diastolic part of the doppler curve (A), pathologic absent diastolic flow (B) and recovery after the treatment (C).

C. Abnormal cardiac rhythms

Fetal arrhythmias are encountered in 1-2% of pregnancies and 10% of these are associated with some form of fetal mortality or morbidity, including structural heart disease, fetal death and neurological complications. The most frequent types of arrhythmia are supraventricular arrhythmias of which the innocent premature atrial depolarizations make up 85%; 10% are tachycardia with a fetal heart rate of over 180/min. [15]

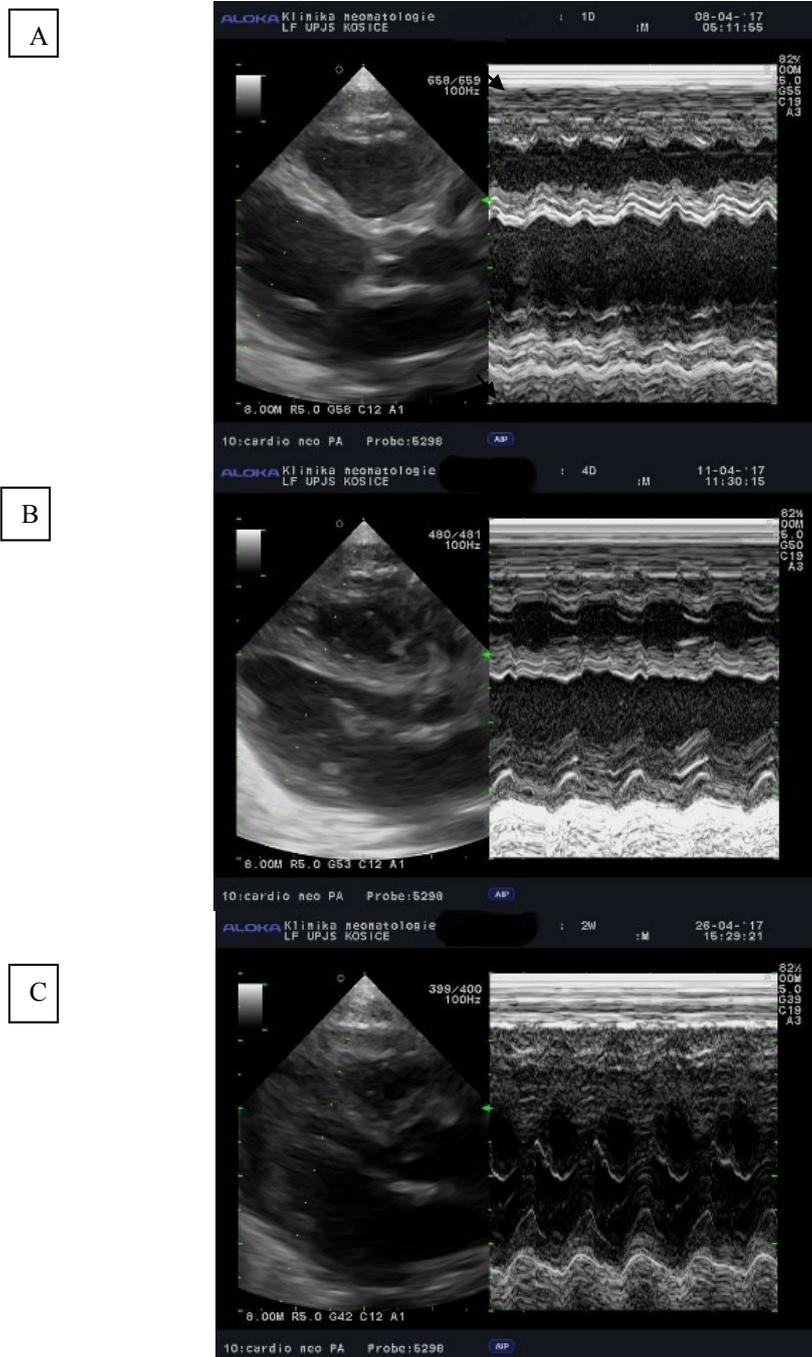


Figure 4. Changes of the cardiac contractility in newborn with congenital hydrops. *Changes of the cardiac contractility (A), after the cardioversion and (B) slow recovery after the inotrope support (C).*

There are data, which suggest that there are autoregulation mechanisms of cerebral blood flow in fetuses with congenital heart disease that enhances cerebral perfusion. [16] Similarly, the autoregulation mechanisms try to maintain stable cerebral blood flow and exchange of metabolically important substances in cerebral circulation of neonate and therefore to protect newborn's brain mainly from hypoperfusion and hypoxia. These mechanisms are effective in the particular range of blood pressure values, below which they become ineffective, causing brain tissue suffering. Brain tissue ultrasound with Doppler measurements of cerebral blood flow is powerful tool, which allows clinician to evaluate the blood flow state in real time and helps to decide if further therapy of cardio-pulmonary system is needed.

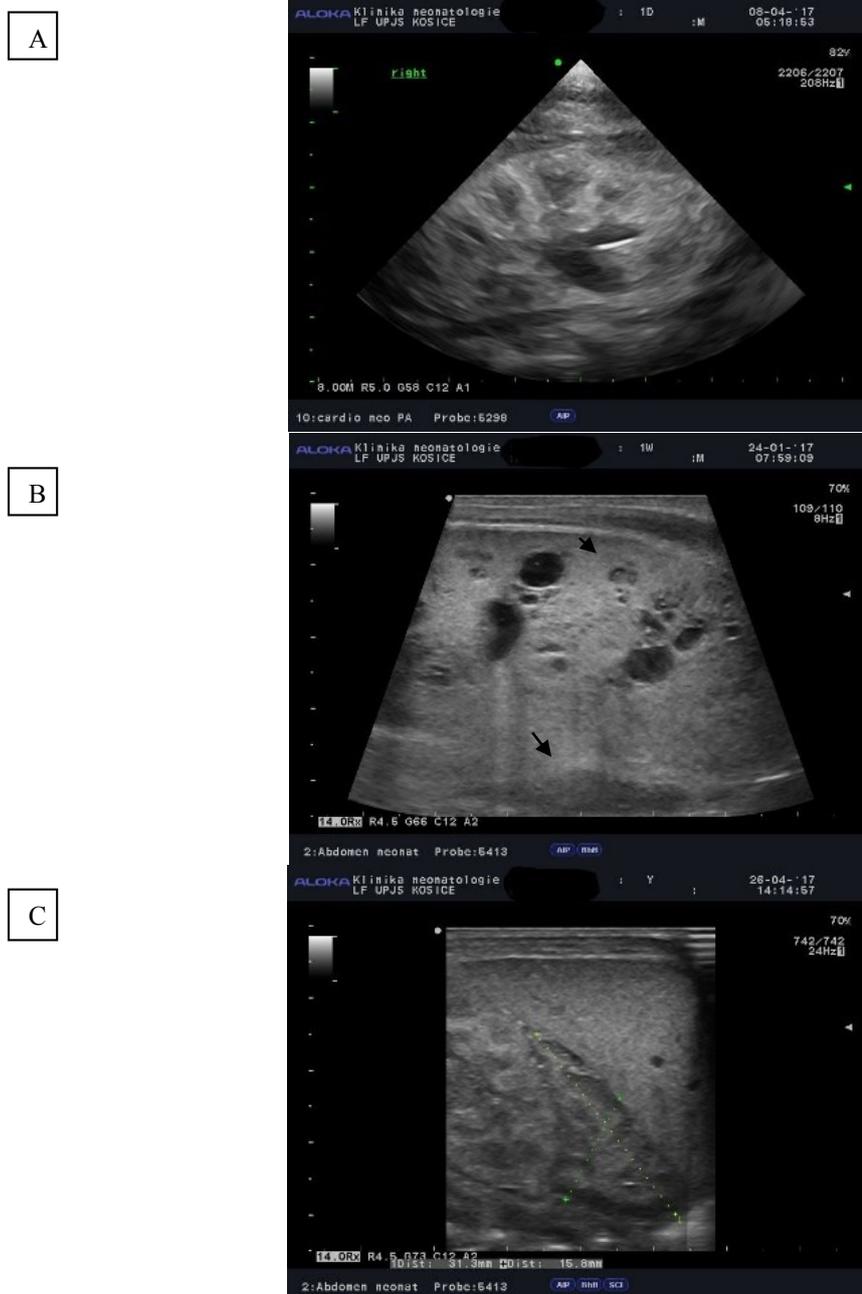


Fig. 5. Ultrasound of the morphologic abnormalities in the kidneys,

Normal kidney (A), autosomal recessive polycystic kidney disease (B) and severe hypertrophy of the suprarenal gland in newborn with congenital adrenal hyperplasia

V. ULTRASOUND OF THE KIDNEY

The ultrasound of the kidney is part of the neonatal screening prenatally and postnatally. The most common lesions are related to the dilatation of the pelvic system. After delivery it is also important to verify the dimensions of the kidneys, discover if there is no agenesis and evaluate the suprarenal glands. Congenital abnormalities of the kidney and urinary tract (ureter, urethra and bladder) are some of the commonest abnormalities identified on ultrasound during pregnancy. Antenatal hydronephrosis is seen in up to 1 in 200 pregnancies. This refers to a dilatation in the collecting system of the kidney that may be physiological, or due to obstruction or reflux. Other possible findings include kidneys that are abnormal in appearance and / or position or bladder abnormalities [16], some of which are shown on Fig. 5.

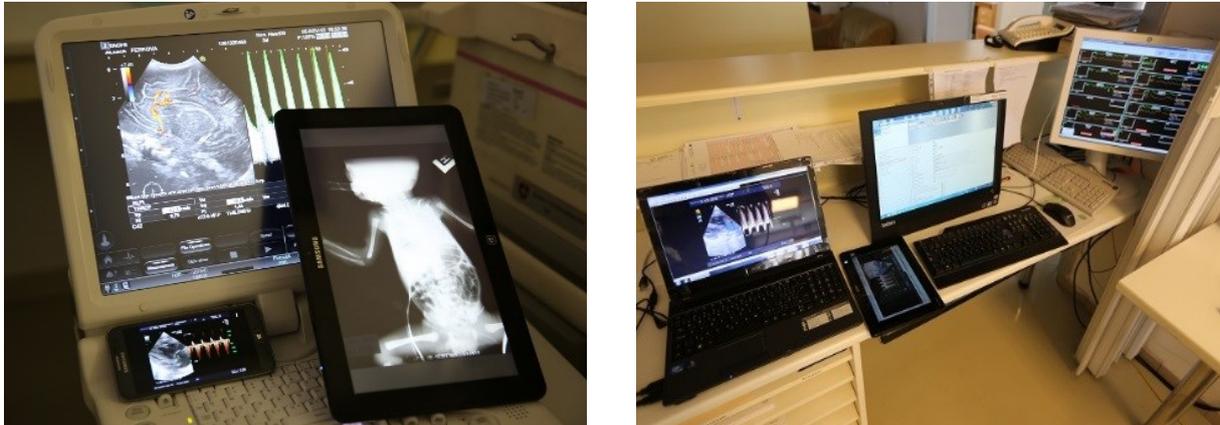


Fig. 6. Hardware used for the data processing

ACKNOWLEDGMENT

The authors presented several clinical situations when bedside ultrasound giving quick information about the changes in the organs giving important information for the clinician bedside. Medical documentation is all over the word based on written data. The physicians trying to classify the disease and select the optimal interventions or treatment. The results of the investigation are printed on papers, recorded or stored in digital media, but the most important is to write the explanation of the scans and findings. It was developed a system enabling the accurate archiving and management of ultrasound images gathered during a clinical screening trial. It is based upon a Windows application utilizing an open-source DICOM image viewer and a relational database. The data process is shared between ultrasound and notebook using secure Wi-Fi. The storage of the scans is done during recording simultaneously in two places.



Figure 7. Projecting data to the big screen during the rounds

The scans are retrieved from the database using tablet and projected to the central digital screen installed closely to the incubators, one big screen for 8 cases. These image records may be processed, stored in a DICOM viewer or export them to external media.

CONCLUSION

The new era need quick evaluation and visualization of the important data. In the neonatal intensive care unit, the newborns are coming in critical condition, the physicians must to act quickly, gently and adequately. The decisions are not easy. The process of the decisions is usually just on written form, the scans are done with x ray, usually one or two pictures, the ultrasound allowing to do several scans from the brain, heart, kidneys, liver, spleen and abdomen. On the other side it is possible to measure several Doppler measurements on the different vessels. It is the huge amount of information, the clinician must to understand them. Our system of the visualization filling several crucial roles in the process:

- Real time data storage
- Discovering crucial abnormalities
- Following closely the decision process of the physician
- Allowing discuss the findings with the consultants and experts
- Enables easy return to the scans done before
- Enables discuss the scans during the daily rounds
- It is used for education purposes for physicians, nurses, students
- Giving a new format for the explanation of the severe abnormalities for parents and caregivers
- Enables monitoring of the treatment process and it's effectivity
- Continual education tool for the staff
- Easy return to the older cases for scientific work and publications.
- Cheap and easy way to work with digital data

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