BABYLUX

Programme	CIP – Competitiveness for innovation
Type of Action	Pilot B
Project Title	An optical neuro-monitor of cerebral oxygen metabolism and blood flow for neonatology
Acronym	BabyLux
Project n.	620996

D3.1 REPORT ON DEMONSTRATION OF EXISTING PROTOTYPES

Work Package	WP3
Lead Partner	ICFO
Contributing Partner(s)	PoliMi, HP, RH-Neo, IRCCS Ca' Granda
Security Classification	PU (Public)
Due date	31/03/2014
Date	31/03/2014
Version	Final

The BabyLux project (620996) is co-funded by the European Union under the CIP competitiveness and innovation framework program 2007-2013.

Document history

Version	Date	Comments	Authors
1.0	19/03/2014	First draft	D.Contini (PoliMI)
2.0	26/03/2013	Revised draft	T.Durduran (ICFO)
2.1	31/03/2014	Final draft	T.Durduran (ICFO)
Final	31/03/2014	Final editing	A.Torricelli (PoliMi)

The work leading to these results has received funding from the European Community's CIP competitiveness and innovation framework program under grant agreement n°. 620996.

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1. Executive Summary

This deliverable describes the work performed in the TASK 3.1 Demonstration and Training Sessions for Clinical End-Users. The existing diffuse correlation spectroscopy (DCS, Partners: ICFO, HP) and time resolved spectroscopy (TRS, Partner: PoliMi) systems were utilized to demonstrate the work-flow and functioning principles to the clinicians groups involved in the project (IRCCS Ca' Granda and RH-Neo). This took place in two separate sessions at PoliMi facilities and detailed feedback from the clinicians was obtained which is now being considered in the design and development of the hybrid system proposed in the project. Furthermore, this forms the basis of the training of the clinicians in the use of the final system to be developed.

2. Introduction

The aim of the task 3.1 Demonstration and Training Sessions for Clinical End-Users is double: a) obtaining a feedback on the existing solutions so as to drive the development of specific characteristics of the proposed solution; b) training of clinical end-users in order to take confidence with the particular TRS and DCS systems that will be integrated together. Two workshops were organized in order to accomplish the two objectives described above.
This document is divided into 4 parts. In the first part, a description of the two interactive demonstrations is provided (Section 3). In the second part, a brief description of the operative procedures for the use of TRS and DCS prototypes employed in the workshops is presented (Section 4). In the third part, a series of comments, raised by end-users during the tests of the two prototypes, is listed (Section 5). Highlighted criticisms of the present instruments were thought with a view to the use of the integrated system in the neonatal Intensive Care Unit (NICU). In the last part conclusions are presented (Section 6).
In the appendix, photos taken during the workshops and list of participants are provided.

3. Demonstration of Existing Prototypes

Two different workshops were organized for the end-users training on Diffusion Correlation Spectroscopy (DCS) and Time Resolved Spectroscopy (TRS).
See appendix A for pictures of the two events.

3.1 Description of DCS workshop

A training session for DCS was organized at the functional Near InfraRed Spectroscopy (fNIRS) laboratory at Politecnico di Milano on 21/01/2014. In order to achieve this goal, ICFO and HP transported their jointly developed system from Barcelona, Spain. The goal of this session was to illustrate the main principles of DCS, to illustrate the main design principles for this commercial product, to obtain feedback from clinicians as well as other project partners about the system user-interface, design, the software and the probes. The attendance was not limited to the clinical partners (RH-Neo, IRCCS Ca' Granda) and it also involved PoliMi, PQ, Loop and IPT. This enabled a discussion on the clinical use related aspects as well as component and design related aspects.

The system is an eight-detection, four-source channel DCS system that has recently been licenced from ICFO to HP (see Fig. 1). The presentation involved a half-hour demonstration of the system including a real-time in vivo measurement on the human arm followed by a half-hour discussion on various aspects. Further feedback was obtained during the following sessions of the kick-off meeting which was co-located with this activity. A photograph of the system is shown below. Further details of the system are described online at http://www.hemophotonics.eu and by Durduran et al. NeuroImage 85:51-63, 2014.

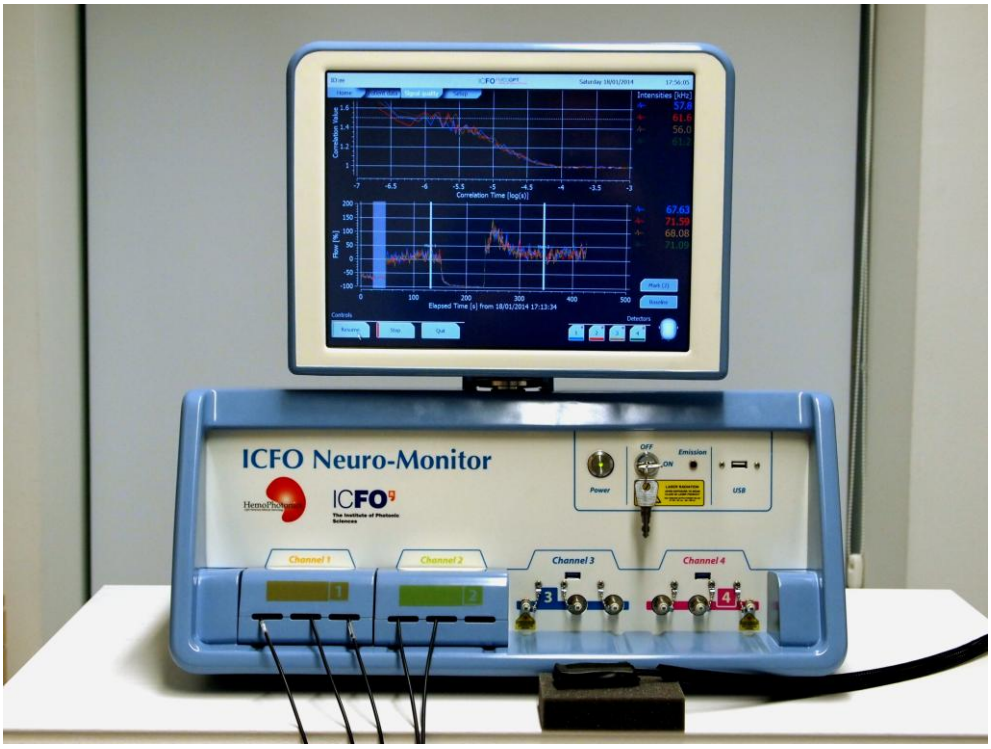

Fig. 1: Photo of the DCS system used during the training session

3.2 Description of TRS workshop

A training session for TRS was organized by PoliMi at the functional Near InfraRed Spectroscopy (fNIRS) laboratory at Politecnico di Milano on 03/03/2014. The event was structured for the clinical end users of the project in order to explain the principle of the technique and to obtain a feedback for the design of the TRS module. Ten people working at IRCCS Ca' Granda attended the short course (see appendix B for the complete list).

After a brief presentation (45 minutes) about the basic principle of Diffuse Optical Spectroscopy and in particular about TRS, a laboratory demonstration (2 hours) was carried out.

The employed TRS instrument was a two channel laboratory prototype, normally used as test bed for novel technologies and for student training (see Fig. 2).

Fig. 2: Photo of the TRS system used during the training session

This TRS system is based on a couple of pulsed diode lasers, as light source, operating at 690 nm and 829 nm with 80 MHz repetition rate (PDL, Picoquant GmbH, Germany). After the laser heads, light is injected into multimode graded index fibres (50/125 μm) by means of a custom-made coupler. It combines a couple of neutral density attenuators (NT43-770, Edmund Optics GmbH, Germany), with a total variable attenuation in the range of 0-80 dB, and a standard FC fibre optics coupler. Variable attenuators are needed during measurements on biological tissues to equalize the signal at the two wavelengths or during acquisition of the instrument response function (IRF) to avoid damages of the detectors. After the attenuation stage light passes through an optical 2X2 switch (LEONI Fiber Optics GmbH, Germany, maximum switching rate 5 ms), which allows the wavelength Space

Multiplexing (each wavelengths shined in a different point of the sample at time). Photons reemitted by the sample are collected by two custom-made glass fibre optic bundles (Loptek Glasfasertechnick GmbH, Germany) with 3 mm diameter and 0.49 numerical aperture. After the bundles, the signal is equalized by step-variable neutral density attenuators (NDC-50S, Thorlabs, Newton, NJ, USA). Then the signal is coupled to the active area of a photomultiplier tube (PMC-100, Becker&Hickl, Germany) by means of a proper optical lens system. In the optical system a band-pass filter (OPMI-0037, Semrock, USA) and a shutter (SHB1, Thorlabs, Germany) were inserted to avoid the PMTs damage due to the ambient light. The PMTs are cooled by an internal Peltier system driven by external home-made circuits. After the PMTs the electrical signals are amplified (HAFC-26, Becker&Hickl, Germany). The acquisition of time-resolved reflectance curves is accomplished by 2 parallel and identical boards (SPC130, Becker&Hickl, Germany) for TCSPC.
All the system is controlled by a homemade software, written in C-language in the LabWindows/CVI environment (National Instruments, TX), interfaced to a micro-controller unit (dsPIC30F2010, Microchip Technology Inc., AZ). For a fully description of the instrument see R. Re et al. RSI 81, 113101 (2010).
A measurement of venous occlusion of the arm on an adult volunteer was performed in order to explain the operating principle of the instrument. The data acquired were analysed after the experiments and discussed together.

4. Measurement Procedures

In this section the operating procedures for the use of the two instruments employed during the training sessions are briefly described.

4.1 Operating procedures of the DCS instrument

The DCS system is a pre-commercial prototype developed by a two-project at ICFO which is now commercialized by HP. The main design goal was to automatize the operation for use at a clinical environment with extensive quality control and safety procedures. The main steps of the operation are as follows:

- Plug in and turn on the instrument which involves a single power button.
- The software launches automatically and the user has to log-in (part of the data protection procedures)
- Depending on the credentials of the user the main interface is launched either at a “basic clinical” or “advanced, technical” mode. We have used both modes in the demonstration.
- The software starts with a pre-defined mode that contains all the details needed for a measurement. The user can choose to load other pre-defined modes or define a new one.
- The software instructs the user to turn on the laser using the interlock key (a required safety feature).
- The system does an internal check and confirms that all sources and detectors are functioning properly that the laser power is within predefined limits and detectors are responsive.
- The system checks whether the pre-defined probe(s) is plugged in using built-in sensors. If not, instructs the user to plug in the correct probe(s).
- The user is instructed to either place the probe on a pre-defined calibration phantom or skip this step and go to the tissue. If the phantom is utilized, the system checks that all measured parameters are within the defined specifications and otherwise instructs the user in a step-by-step fashion to take steps to fix any problems.
- The next step is to attach the probe(s) to the tissues of interest and the system repeats the checks that were done on the phantom measurement. If it encounters any problems, for example, light leaks, it instructs the users in a step-by-step fashion to take remedial actions.
- The measurements are now ready to start. The data are acquired and blood flow index is calculated in real-time.
- If needed, the user defines a baseline period where the data is displayed relative to this period.
- All plots are pre-defined in the loaded configuration files. In the “basic clinical” mode, the user only sees calculated indices, while in the “advanced, technical mode” the user has access to raw data and other variables.
- Throughout the measurement, the user is able to adjust the scales of the plots, make Marks that are inserted in all output files, enter comments about different marks, enter a screen where a report can be typed up, send/receive data from other instruments and monitors.
- When the measurements are over, the user stops the measurement, if desired exports the data to an external drive, turns off the laser key and then the system.

4.2 Operating procedures of the TRS instrument

The TRS system employed during the workshop is a laboratory prototype used in research environment, for this reason the operating procedures are redundant and directly controlled by the operator without any automation. The main steps of the operation are as follows:

- Plug in and turn on the instrument.
- Wait the warming up (around 3 hours).
- Set the measurement parameters (e.g. acquisition time, length of the measurement, file output name) in the instrument software panel, according to the measurement protocol.
- Prepare the probe for the optical fibers and attach it to the subject skin.
- Open detector shutters and detector attenuators in order to evaluate the noise level due to the ambient light, if necessary shield the probe.
- Equalize the signal intensity for both the wavelengths adjusting the attenuation level of both laser heads and detector.
- Perform measurement.
- Close attenuators and shutters.
- Remove the optical probe from the subject skin.
- Record the instrument response function.
- Turn off the instrument.

Data analysis is performed using different software that can be used both on line and off line. The analysis software needs inputs from the operator (measurement parameters, essential model parameters etc.).

5. Feedback from end-users

In this section feedbacks from end-users are provided. The comments and criticisms highlighted by end-users were collected directly during the discussions following the training sessions. These comments are generally referred to both techniques (DCS and TRS) even if in some cases they are specifically referred to the particular instrument used during the training session.
It is possible to distinguish three typologies of comments/criticisms: the first related to hardware issues, the second related to software issues and the third related to procedure issues.

The feedbacks regarding hardware are the following:

1. The dimensions of the current instruments are not suitable for the use in a NICU in particular for TRS instrument. This is due to the fact that both DCS and TRS instruments used during the training sessions were multichannel systems.
2. The system should be mounted on a trolley to be easily moved in the NICU.
3. The robustness of the structure is important for the daily use in the NICU.
4. Fibres connecting control unit and probe should be not too much rigid in order to be bent inside the cot.
5. The probe in contact with the baby's head should be soft and lightweight in order to press gently on the skin of the newborn.
6. The probe should be skin-compatible to avoid allergies and pressure sores as much as possible.
7. The warm-up of the instrument cannot be longer than 30 min, this is a criticism highlighted in particular for the TRS instrument employed during the training session.
8. The system should be able to run at least in a stand-by mode on a battery for ease of transport between different cots and quick deployment.
9. The system should check automatically its status, for example: an accidental exposure to a high level of light should be detected before damaging by the system itself without any interventions by the operator.
10. The system should be able to turn off all lasers once a probe disconnect is detected within a short time (<1 s) for safety. This is partially implemented in the DCS system.
11. The system should be quiet. The clicking of the optical switches in the current systems is a problem in the quiet environment of the NICU. It also should not produce any significant heat.

The feedbacks regarding software are the following:

1. The number of input for the instrument's software should be reduced at the essential information of the patient, without any measurement parameters.
2. Measurement software and analysis software should be the same.
3. The final output of the instrument should be a couple of numbers on a screen regarding the tissue oxygenation and the blood flow level, with a graph in order to evaluate trends of these parameters.
4. The output of the software should be integrated with the outputs of the other monitors (pulse oximeter, blood pressure etc.) in the same data stream.
5. It should be envisaged the possibility to insert comments and markers during the measurement recorded together with the data of tissue oxygenation and blood flow.

The feedbacks regarding procedure are the following:

1. The final instrument will must be a “one button” instrument, this means that all the calibration procedure should be automated with minimal interventions by the operator.
2. The system calibration (e.g. Instrument Response Function for TRS) cannot be taken for each measurement, an alternative way to calibrate measurement, preferable in an automatic way, is needed.
3. The calibration phantom measurement procedure should be simple and should be needed less frequently than it is now. It should be recorded and should provide tractable information about the health of the system.

All these comments will be considered in the design of the DCS-TRS integrated instrument in order to tailor as much as possible the instrument for the employment in a NICU.

6. Conclusions

In conclusion, the sessions were deemed to be successful. The technical partners received valuable feedback and the information was relayed to the components manufacturers and the designers. Overall, this activity has provided invaluable information and we will continue to carry out basic activities like his. Partners were happy that they had the opportunity for this interaction early-on.

Appendix A

List of participants from the clinics of the end-user training session on DCS

Monica Fumagalli, PhD, MD (IRCCS Ca' Granda)
Martorana (IRCCS Ca' Granda)
Francesca Dessimone (IRCCS Ca' Granda)
Ida Sirgiovanni (IRCCS Ca' Granda)
Agnese De Carli (IRCCS Ca' Granda)
Gorm Ole Greisen, PhD, MD (RH-Neo)

List of participants from the clinics of the end-user training session on TRS

Monica Fumagalli, PhD, MD (IRCCS Ca' Granda)
Ida Sirgiovanni (IRCCS Ca' Granda)
Laura Bassi (IRCCS Ca' Granda)
Agnese De Carli (IRCCS Ca' Granda)
Francesca Dessimone (IRCCS Ca' Granda)
Silvia Pisoni (IRCCS Ca' Granda)
Sofia Passera (IRCCS Ca' Granda)
Sara Uccella (IRCCS Ca' Granda)
Paola Schiavolin (IRCCS Ca' Granda)
Giuseppe Damiano (IRCCS Ca' Granda)

Fig. 3: Pictures taken during the training sessions.