

Wearable systems in Neonatal Care: challenges and perspectives

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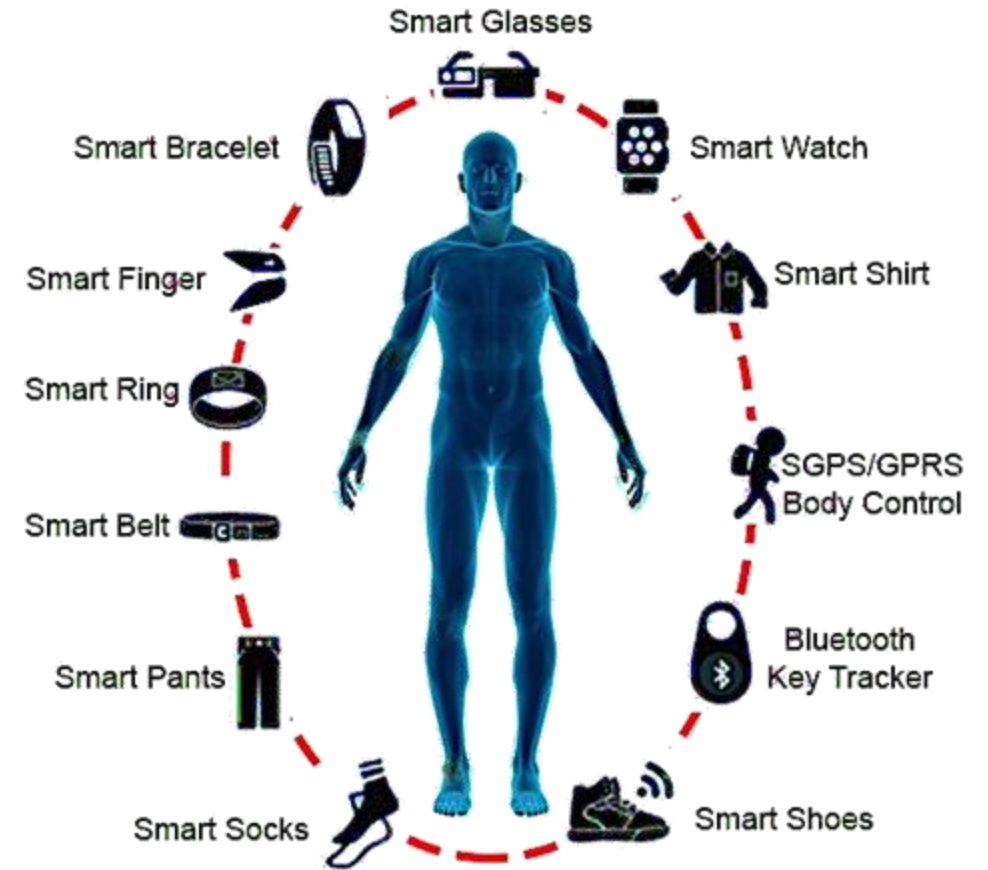
7th EPTRI Webinar – 17/09/2024

INTRODUCTION

The term «***Wearable technology***» includes a plethora of devices developed to be worn and accessible by the user.

Main features:

1. "always on" and accessible by the user
2. controllable and interactive,
3. augmenting the senses and the processing function-capability
4. Working in synergy with the body, not limiting the user's functions and mobility, non intrusiveness concept



INTRODUCTION

Wearable systems are:

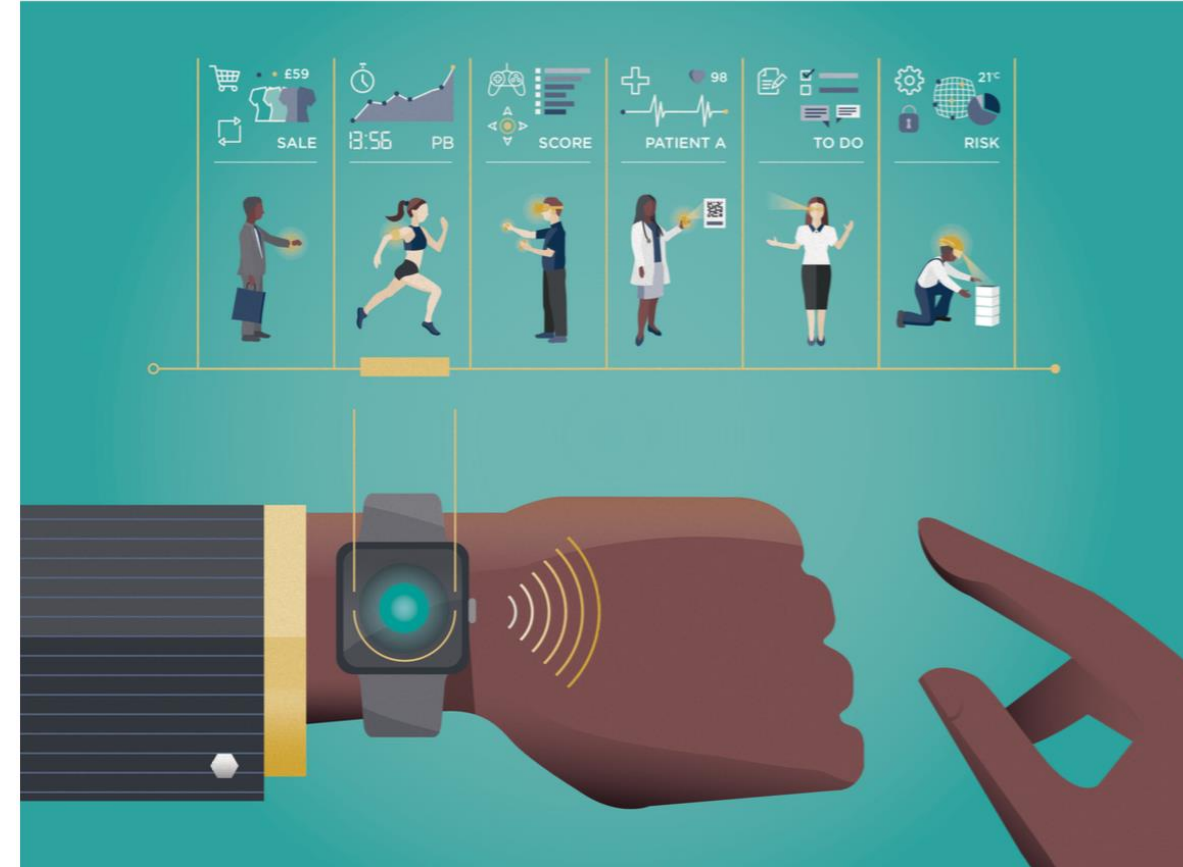
Etimologically ... wearable = onto the body

Technologically ... interlinked measurement systems

For Sport ... towards performance

For Work ... safety, health and performance

For Health... diagnosis, cure, rehabilitation, prevention



INTRODUCTION

Wearable Health Systems (WHS) or Wearable Biomedical Systems (WBS) are integrated systems on body-worn platforms like wrist-worn devices or “biomedical clothes”, offering pervasive solutions for continuous health status monitoring through non-invasive biomedical, biochemical and physical measurements.

WBS would enable monitoring of patients over extensive periods of time, and they can be proposed to offer affordable and interactive healthcare, anytime, anywhere for anyone which is the future of healthcare.



WEARABLE SYSTEMS IN NEONATAL CARE

In Medicine WBS are dedicated to:

- Empower functions
- Monitoring functions (human &/or environment)
- Therapeutic actions
- Replace functions

4 different typologies:

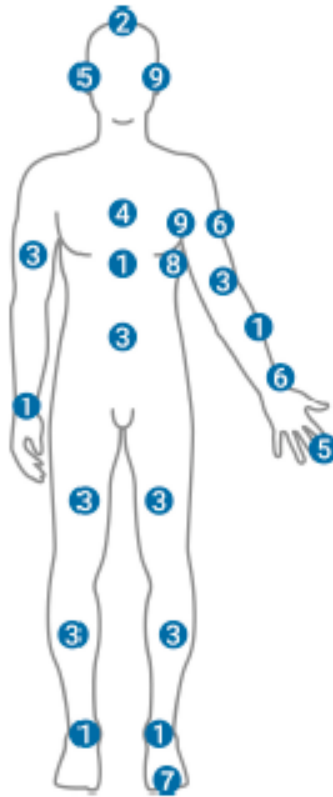
- Sensorized garments
- Body worn Accessories
- Exoskeletons
- Prostheses



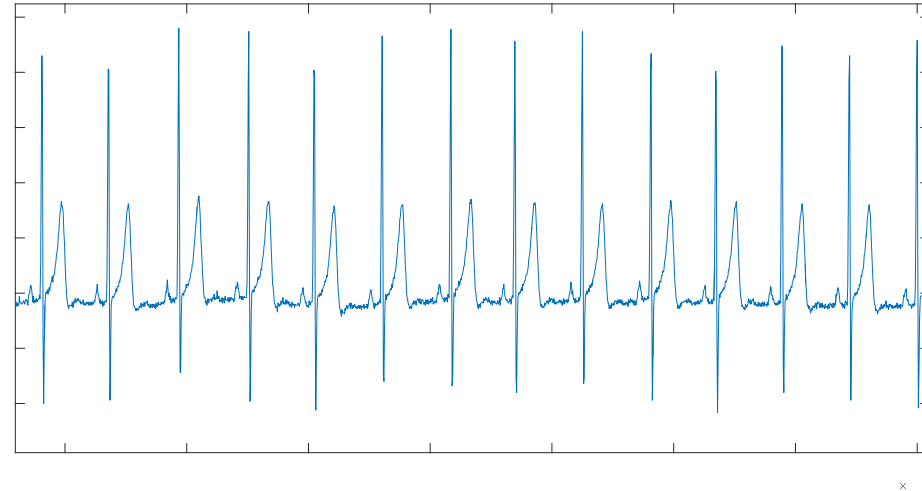
WEARABLE SYSTEMS IN NEONATAL CARE: SENSORIZED GARMENTS

Textile research has produced advanced fibers (conductive, optical, embedding nanocapsules, ...) enabling the production of ultratechnical fabrics with multiple properties:

Electrical
Sensing
Actuators
Chemical
Biological



No.	Signal
1 =	ECG
2 =	EEG
3 =	EMG
4 =	Respiration
5 =	Blood gas
6 =	Blood Pressure
7 =	Interface pressure
8 =	Resistance
9 =	Temperature

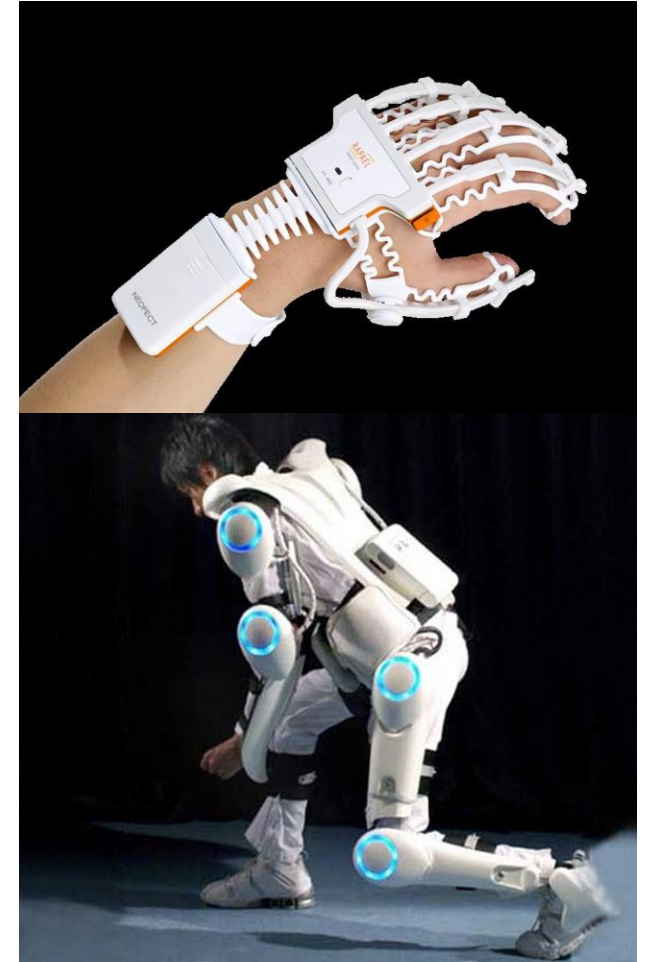


WEARABLE SYSTEMS IN NEONATAL CARE: PROSTHESES AND EXOSKELETONS

Prostheses are wearable solutions to replace not only anatomical parts but – above all – lost human functions.

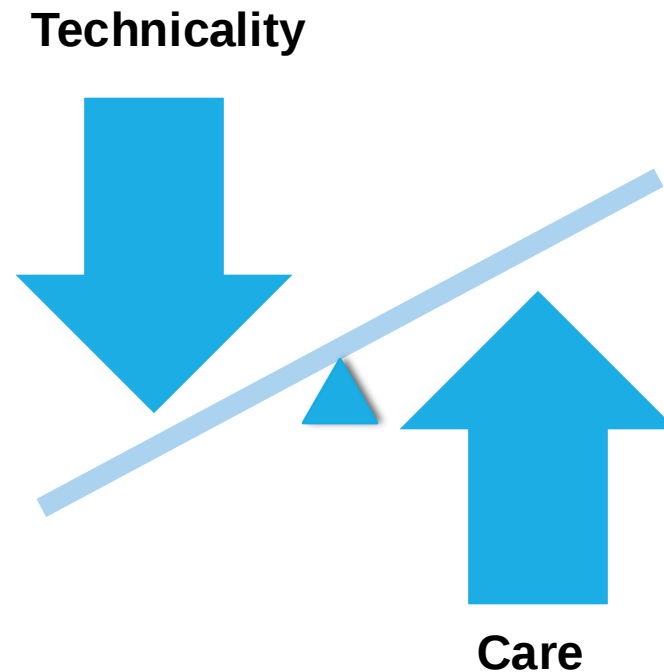
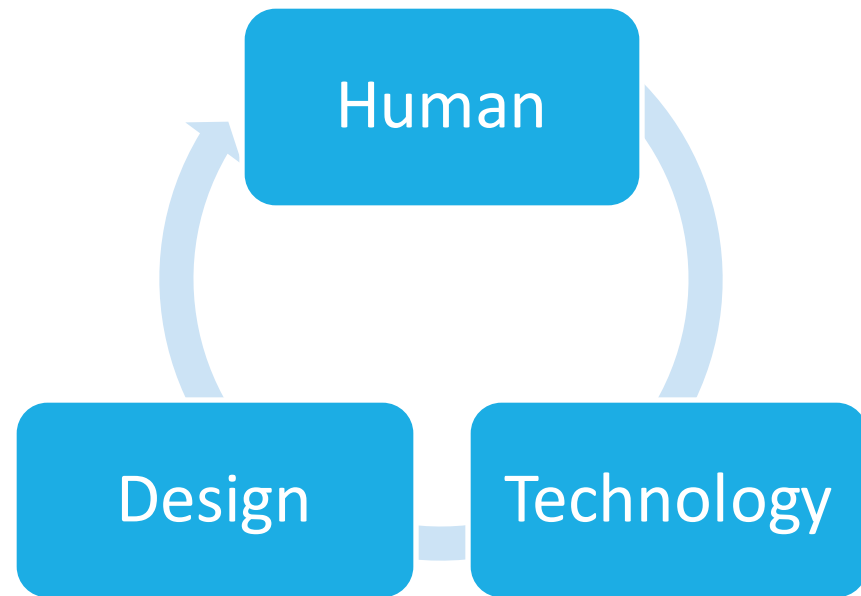
These systems embed several technologies and materials which are all essential for their full success.

Exoskeletons are external wearable structures and systems able to empower or reinforce new, weakened or lost functions. They embed an important complexity of design, mechatronics, materials, sensors and software. Applications in rehabilitation, workplace ergonomics, and sport are the more relevant.



WEARABLE SYSTEMS IN NEONATAL CARE

The “Care” is the new clinical approach for the therapy of newborns in Neonatal Care, (and in specifically Neonata Intensive Care Unit) and/or in the first two-hours lifetime, to assure the baby physical and comfortable experiences that could guarantee the best conditions for the most proper neuromotor development.



WEARABLE SYSTEMS IN NEONATAL CARE

Ensure monitoring (Cure)

improve comfort, protection, physical and psychological wellbeing of the newborn (Care)

- Replace the standard adhesive electrodes;
- Maintain clinical quality signal;
- Interface to monitor hospital.
- Increase thermal protection

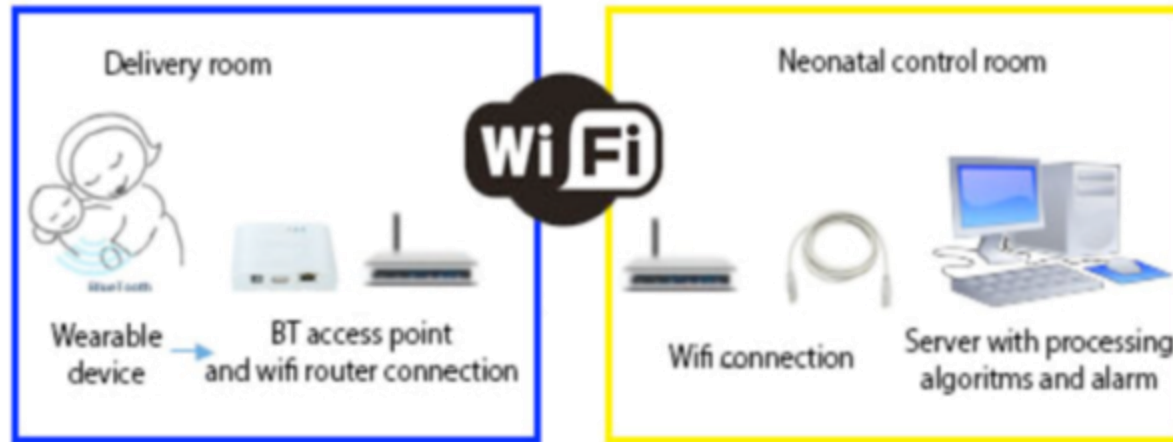


From Cure
... to Care



WEARABLE SYSTEMS IN NEONATAL CARE

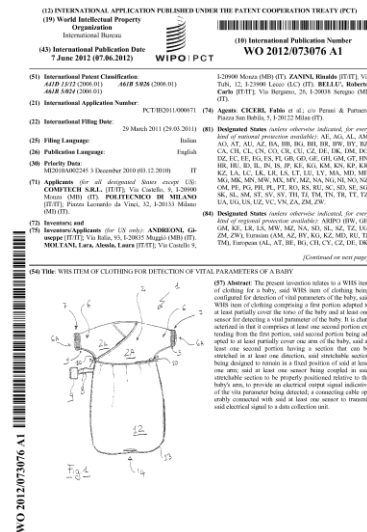
RCT for the EVALUATION OF COMPLIANCE OF MOTHER AND HOSPITAL STAFF TO WEARABLE MONITORING SYSTEM of the newborn in the first 2 hours of life.



Innovative solution for monitoring heart rate, breathing and movements of the newborn: it is not intrusive to the baby and it allows the contact with the mother or the care activities provided by the department staff.

The clinical study aimed at assessing:

- the compliance of the hospital personnel (N=15);
- the compliance of the mother and other relatives (N=30+30);
- the reliability of a new monitoring system applied in the first 2-4 hours of life of a newborn during the bonding procedure in hospital.



WEARABLE SYSTEMS IN NEONATAL CARE

RCT for the EVALUATION OF COMPLIANCE OF MOTHER AND HOSPITAL STAFF TO WEARABLE MONITORING SYSTEM of the newborn in the first 2 hours of life.



From the reliability point of view the wearable biomedical sensors provide excellent results.

From the point of view of user compliance and acceptance, the clinical trial shows very positive scores in particular by mothers and relatives this indicating the high usability and high expectation from the introduction of such a system in hospital practice.

Nurses and midwives started with a certain degree of skepticism but turned into good acceptance and better scores than the standard procedures after a short training period

Mothers and Fathers showed an immediate and greater acceptance of the wearable monitoring system. Mother and Fathers gave the same results to the assessment of ergonomics, usability, service quality and usefulness. Both agreed on the following statements (and for all the factors: mean rate = 9 and mode value =10):

- Sensor ergonomics and wearability were evaluated as excellent;
- Software usability was rated very good;
- Perceived quality of wearable monitoring system was assessed with excellent average rate;
- The expected utility of the wearable monitoring system considered very positive.

In relation to perceived safety and satisfaction, mothers slightly preferred the wearable monitoring system. Excellent ratings occurred for both monitoring systems, the traditional one and the innovative method. On same topics, fathers attributed excellent ratings to both monitoring system.

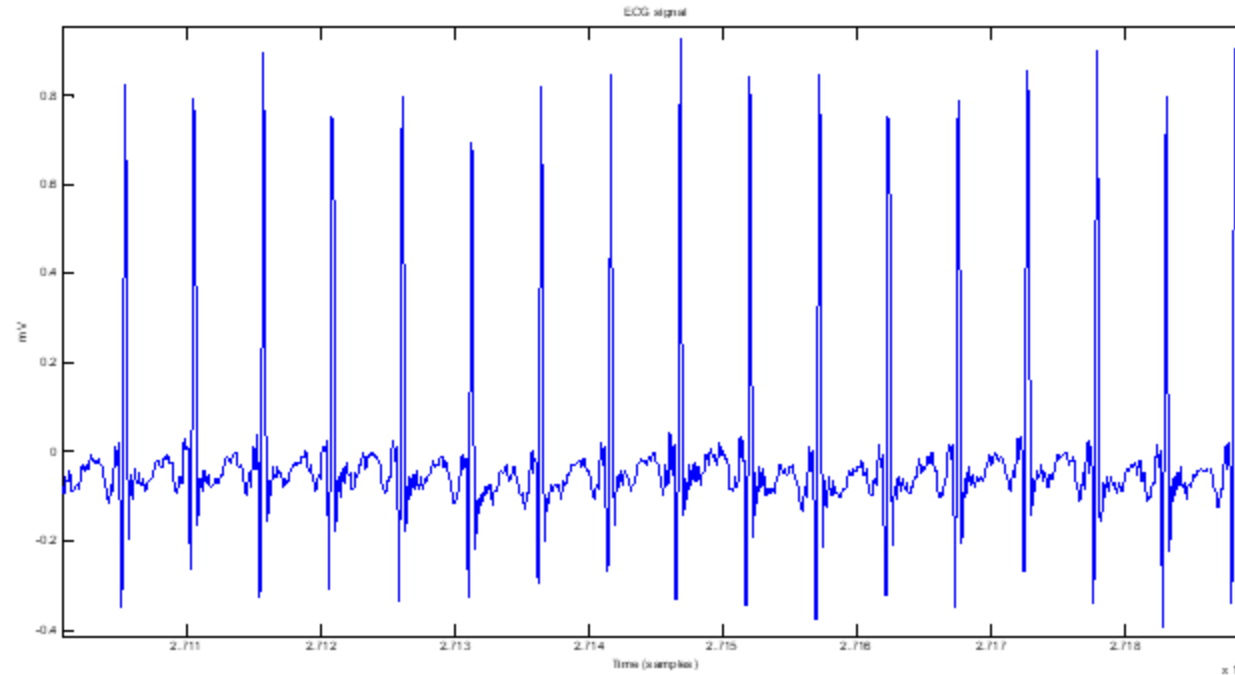
WEARABLE SYSTEMS IN NEONATAL CARE

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The recorded ECG signal is excellent in quality so allowing a correct computation of the beat-to-beat heart rate.

Example of the raw ECG signal (no filtering) from textile electrodes in newborn no. 10204.



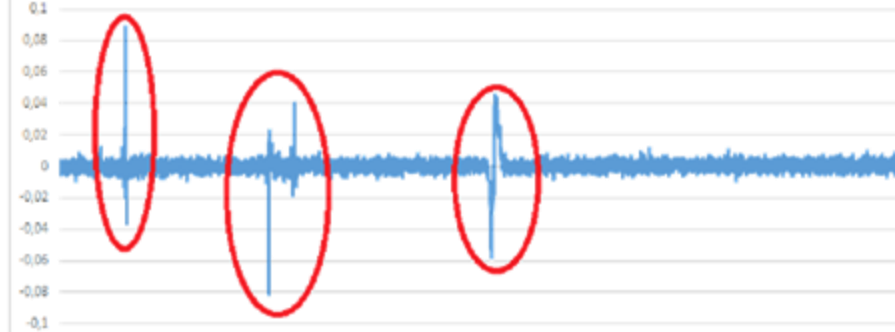
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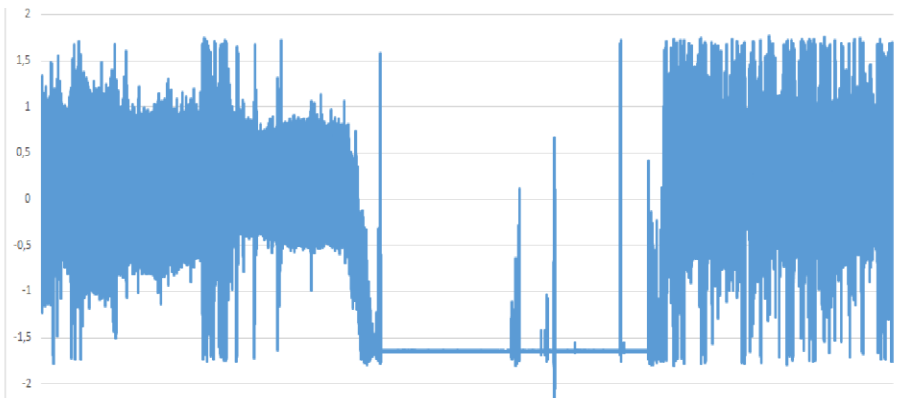


The Performance Index (P, measure unit: %) is defined as follows:

$$P = 100 \times \frac{(\text{Total acquisition time} - \text{Time with corrupted signal})}{\text{Total acquisition time}}$$



Signal artifact caused by the movement of the electrodes to the skin.



Signal interruption caused by the posting of snap buttons.

No.	Index	Duration (s)
1	72,57	5475
2	98,54	8364
3	97,13	2888
4	60,77	3699
5	94,70	7382
6	94,82	6793
7	96,52	892
8	59,16	6533
9	95,00	920
10	80,78	4380
11	97,82	6730
12	88,18	6170
13	98,42	3808
14	95,50	6085
15	89,04	8795
16	78,75	1026
17	83,26	4182
18	87,63	5264
19	34,09	5867
mean	85,01	4988
St. dev.	17,40	2441
median	91,87	5565,5

Average percentage of high-quality signal is **75.8% ± 18.9 SD (median 85.6%)**.

If including events with limited duration (<10 seconds) that will not generate an alarm and therefore clinicians don't consider them:

Performance Index = **85,01% ± 17,4 SD (median = 91,87%)**.

If including also the signal portions with events generating alarm (with duration >60 s, so requiring intervention of the clinical personnel) the final reliability of the ECG signal raises up to **89.8% ± 10.1 SD (median = 94.8 %)**.

CURRENT SOLUTIONS



CONCLUSIONS AND FUTURE PERSPECTIVES

- Wearables systems are now approaching a new maturity level.
- Their application and exploitation is still at the beginning.
- The seamless monitoring is the most promising application.
- Clinical validation and certification represent the most relevant barrier to their introduction into neonatal care (and not only) practice.

CONTACTS

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