34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

Post-operative blood loss monitoring device: a new tool for nursing activities*

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Abstract— **In most medical specialties, after surgery, it is usual to place a drain at the operative site level, in order to assist the blood flow-out if necessary. This drainage allows avoiding the formation of hematomas and contributes to tissues recovery. However, postoperative blood loss can lead to serious consequences. Also, it is necessary to continuously check the blood output volume in order to be able to intervene quickly in case of too significant losses. In daily clinical practice, this task is due to the nursing staff that periodically records the blood level inside the supple bag connected to the drain. However, this method is not accurate about the volume of lost blood and does not reflect the flow of losses which is an important parameter regarding the evolution of the patient setting. We have designed and developed a prototype of a blood loss monitoring device based on the continuous weight measurement of the blood bag connected to the drain. This device is fixed on the bed and is able to instantaneously alert the medical staff in case of abnormal blood flow-out.**

Keywords—**Blood loss, post-operative monitoring, nursing tools, and monitoring device**

I. Introduction

Post-operative blood loss monitoring is essential so as to warn about possible post surgery hemorrhage. In fact, in most medical specialties, at the end of surgery, it is usual to place a drain at the operative site level. The drain is then connected to a supple bag as a blood container. This drainage is used to assist the blood flow-out, if needed, in order to avoid the formation of hematomas at the surgery location and then contribute to tissues recovery. However, postoperative blood loss can lead to serious consequences [1], especially in case of suture rupture for example, where the medical staff has to be alerted in order to intervene as soon as possible. In that way, it is necessary to continuously check the blood level inside the blood container in order to be able to respond quickly in case of too significant blood losses. In routinely clinical practice, this task is accomplished by the nursing team that periodically records, for each patient, the blood loss volume inside the supple bag. But this method presents different disadvantages. Firstly, this visual blood volume measurement is not accurate, and, secondly, it does not appreciate the blood loss flow that is nevertheless a significant parameter regarding the patient setting evolution. At last, it is source of error because when the blood container is full and has to be changed, the risk to forget to add the losses volume due to the different bags is increased. But the most important disadvantage of this method is certainly the risk of non-detection of a hemorrhage episode. Indeed, even if the blood level is recorded periodically by the nurse, there is an important risk of time lag between a sudden blood loss and its discovery, which can be harmful to patient setting.

Some authors have described a blood loss monitoring device [2] based on the continuous weight measurement of the blood container which enables the transmission of the information to a central monitoring unit. Such a system allows the nurse to remote control in real time the patient blood loss volume. But a given blood loss volume do not lead to the same outcomes from one patient to an other, function of some parameters like, for example, the patient's weight, his hematocrit or hemoglobin rate, which would contribute to accept a more or less blood loss volume.

We have designed and developed a prototype of a blood loss monitoring device based on the continuous weight measurement of the blood container of the drainage system. This device is attached to the bed and is able to instantaneously alert the medical staff in case of abnormal blood flow-out.

II. Methods and materials

Our prototype for blood loss monitoring is composed of a main module, in charge of continuous weight measurement and processing, and a command module, which can be either a commonly available PC computer or a graphics tablet, used for main module settings and data recording (Figure 1).

The main module is equipped with a weight sensor, a microcontroller based central unit, control switches, local display and Bluetooth communication capabilities.
The command module, that communicates with the main module trough a Bluetooth communication channel, includes specific software that allows recording patient's parameters,

*Research supported by OSEO Foundation.
Manuscript received March 29, 2012.
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configuring the main module settings and save the computed data.

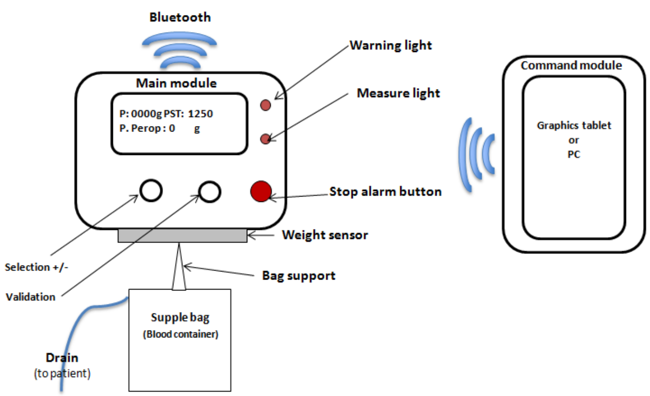

Fig. 1: General configuration of the blood loss monitoring device.

A – Main module hardware architecture:

The main module is built around a PIC32 microcontroller associated to a 8 MO flash memory, input / output ports and other communication capabilities (figure 2).

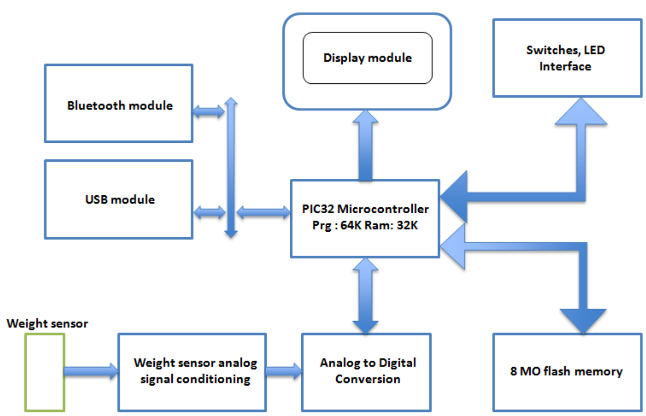

Fig. 2: Main module hardware architecture diagram.

The weight sensor used for this application is a TEDEA Huntleigh 1022 M type sensor, with a sensibility of 0.06 g in order to evaluate the weight of about 3 kg weight bags, equivalent to a volume of about three liters, which is the usual capacity of commonly available redon's drain bags. The analog signal issued from the sensor is then amplified and low-pass filtered in order to fit with the analog to digital converter characteristics. The numerical information is processed by the PIC32 microcontroller that is programmed in the way to generate, in addition to the volume calculation, the detection of blood over-volume and / or blood over flow and the associated alarms. A display module, associated to switches and indicator lights, controlled by the microcontroller program, enable to locally display the volumes and alarms information, and manually control the main module settings and operation. At last, this module is equipped with Bluetooth and USB communication ports that are used, on the one hand, for the transmission of the detected alarms, and, on the other hand, for the communication of information with the command module.

B – Main module software functionalities

The main module software allows to manually enter some patient's characteristics, such as weight, size, genre, pre-operative hemoglobin and hematocrit, in order to calculate the optimal theoretical blood loss volume accepted for a given patient.

According to the patient's characteristics, patient's Body Mass Index (BMI), critical hemoglobin (HbMini), critical hematocrit (HteMini) and Theoretic Blood Volume (TBV) are computed as described below.

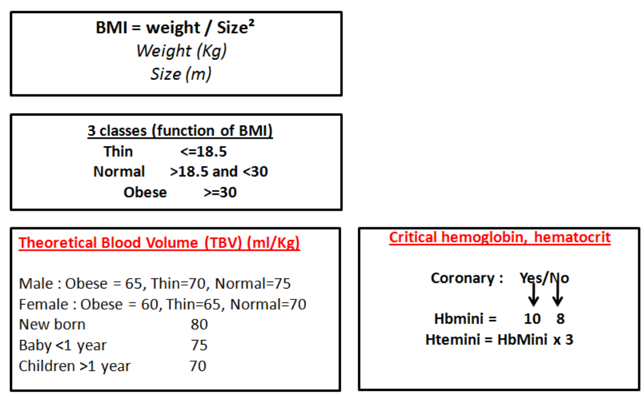

Fig. 3: Theoretical blood volume, critical hemoglobin and critical hematocrit definition table

The main module's software then computed the Theoretical Blood Loss (TBL) using one of the three following models:

1. ***SIMPLIFIED:***
TBL=0.7*weight*(Htepreop - Htemini)/Htepreop

2. ***GROSS [2]:***
TBL=TBV*weight*2*Htepreop - Htemini/(Hbpreop + Hbmini)

3. ***BOURKE [3]:***
TBL = TBV*weight*ln(Hb*preop* / Hb*mini*)

Finally, the main module allows to compute the blood loss volume in real time as a function of the preoperative blood loss (manually hold), the sensor measure, the supple bag weight and the possible supple bag changes. Alarms are performed in the case of excessive losses, that is to say blood loss equal or up to theoretic maximal blood loss (TBL) or important blood flow, that is to say more than 2 ml/Kg/h.

Fig. 4: Blood loss monitoring prototype

C – Functional validation

In order to functionally validate the prototype, we realized different tests to prove, firstly, the correlation between a given injected liquid volume and the weight measurement, and, secondly, the correlation between real injected flow and measured flow. We used a commonly available syringe pump (Alaris® GH) equipped with a 60 ml syringe connected to the Redon's drainage equipment installed on the blood less monitoring prototype. The liquid used for the tests was water. The pump allowed us to regulate the liquid flow and to control the injected volume and flow. The prototype measurement were recorded and compared with the injected flow and volume. A precision of 1 ml for the volume measure and 1 ml/mn for the flow measure were attended.

III. Results

We tested the volume's measure efficiency on 25 volumes varying from 1 to 250 ml (Fig 5). The measuring unit showed good result with at least 1 ml maximal difference.

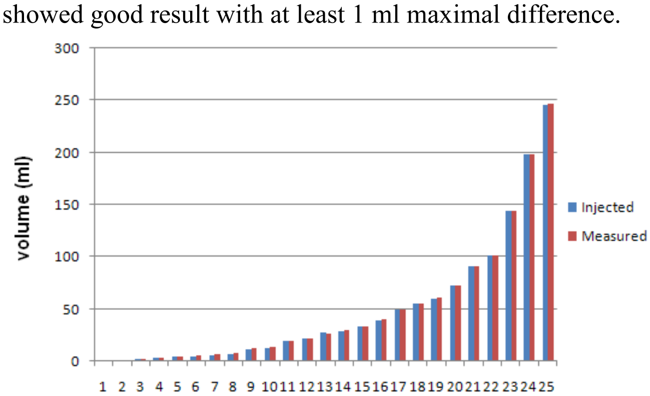

Fig. 5: Comparison diagram for the volume measure

We tested the flow's measure efficiency on 8 different flows varying from 1 to 8 ml/mn (Fig 5). The measuring unit showed good result with at least 1 ml/mn maximal difference.

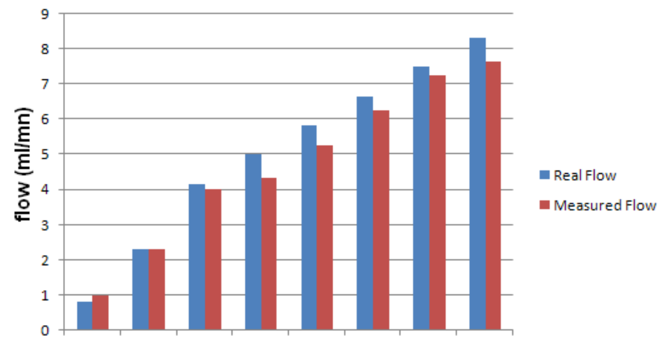

Fig. 6: Comparison diagram for the flow measure

IV. Conclusion

In this paper, we describe a prototype for blood loss monitoring which can be of precious help as a new tool for nursing activities. This prototype was especially designed for automatic and continuous measurement of blood losses volume and flow. In addition, this system is able to adjust the alarm level, function of the patient's criteria, such as the weight, hematocrit rate or hemoglobin, using predefined blood loss models. The functional validation of the prototype, realized in vitro using a controlled syringe pump, showed the accuracy of the flow and volume measurement, but also, the capabilities to correctly activate the alarms in case of abnormal losses flow or volume. This prototype has now to be tested in real situation in order to evaluate the capabilities of blood losses measurements and the user friendly usability.

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