Remote patient monitoring in ambulatory surgery – a pilot study in twenty healthy volunteers

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Abstract

Remote patient monitoring (RPM) allows monitoring of patients both inside and outside healthcare facilities, can enable expedited discharge to their homes and provide early detection of complications as they are still being monitored by healthcare professionals. The Patient Status Engine (PSE) is a wireless RPM that continuously collects physiological data and notifies medical staff when the data is outside the predefined limits for vital signs. The aim of this study was to assess the feasibility of RPM, regarding patient's acceptance, external interference and limitations.

Twenty healthy volunteers were recruited and monitored for the non-invasive blood pressure, pulse oximetry, skin temperature, respiratory rate, heart rate and continuous electrocardiography. The most reliable sensor was the heart monitoring and the least reliable monitoring was the LifeTemp sensor for skin temperature. Most of the patients would be willing to use the PSE for up to two days and most of the volunteers would allow for the data to be transferred to their Hospital records and even would be willing to have a video chat in case of need. The majority of the volunteers would feel safer being monitored after surgery.

To conclude, this study shows that most people are willing to contribute with home monitoring and even feel safer using this technology. RPM's technology will continue to evolve and when used properly can provide a high level of quality data. For selected patients, this technology can be of great help and allow earlier detection of complications in the postoperative period.

Keywords: Ambulatory Surgery, Patient Status Engine, Remote Patient Monitoring, Early Warning Score, Telemonitoring.

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Introduction

Remote patient monitoring (RPM) is defined as the use of technology to monitor patients both inside and outside healthcare facilities. The exponential rise of healthcare technology in clinical settings is leading to the development of reliable monitoring systems. Several studies have demonstrated advantages of using telemonitoring in multiple fields of medicine: follow up of asthma in pneumology (1), heart failure in cardiology (2), hypertension and diabetes in family medicine (3,4). However, there are almost no data on its use in the early postoperative period after surgery.

Postoperative telemonitoring is gaining attention as it can enable expedited safe discharge and may allow early detection of complications. RPM as a support for the ambulatory setting is, more than ever, a close reality that allows patients to leave hospital while still being monitored by healthcare professionals, which can be fundamental in higher risk patients and for more invasive procedures, it may also help those who have no accompanying person at home. The early discharge can be really important, especially at the extremes of age, such as children and the elderly, and psychiatric and neurological diseases.

The Patient Status Engine (PSE) from Isansys® is a wireless remote monitoring system intended for use by healthcare professionals to continuously collect physiological data in home and medical settings (5). Variables that may be collected include heart rate, heart rate variability, ECG-derived respiratory rate, skin temperature, patient positionings and activity, and optionally SpO_2 and non-invasive blood pressure.

The aim of this pilot study was to assess the feasibility of RPM in our population at the patient's usual lifestyle at home, patient's acceptance and to evaluate the effectiveness of the monitoring devices when exposed to the volunteers' daily activities, including external interferences and limitations.

Methods

To carry out this pilot study, twenty healthy volunteers were randomly selected and the following parameters were monitored: non-invasive blood pressure, pulse oximetry, skin temperature, respiratory rate, heart rate and continuous electrocardiography. With these parameters, the Early Warning Score (EWS) was also measured. The EWS is a tool that assignes a numeric value regarding several physiologic parameters (blood pressure, heart rate, pulse oximetry, respiratory rate) to derive a score that is used to identify the early signs of clinical deterioration (6). A score < 4 is considered low risk, a score of 5-6 is considered medium risk and a score > 7 is considered high risk, indicating an increased likelihood of mortality (7) (Table 1).

Table 1 Early Warning Score.

Early Warning Score	
< 4	Low risk
5-6	Medium risk
> 7	High risk

Volunteers were given the PSE that comprises Patient Gateway (an android tablet running Isansys® application) (Figure 1), the Lifetouch Blue sensor (electrocardiographic monitoring), the Lifetemp sensor (temperature monitoring) (Figure 2), the Nonin3150 WristOx (pulse oximetry monitoring) and the blood pressure monitors (Figure 3).

After minimum time for monitoring, volunteers were asked to give feedback through a standardized questionnaire (Table 2).

Figure 1 Patient Gateway.

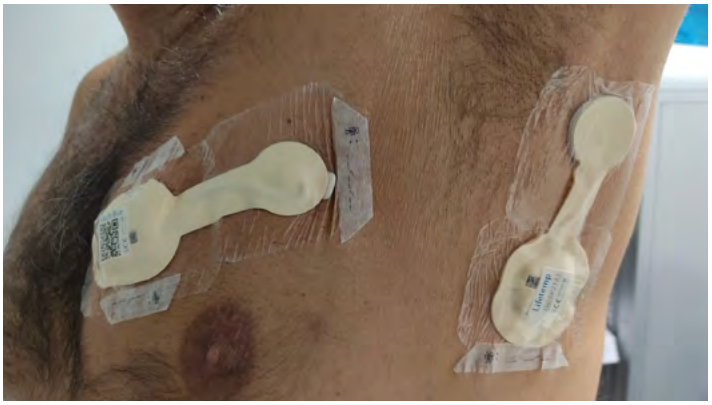

Figure 2 On the left, the Lifetouch Blue sensor (electrocardiographic monitoring). On the right, the Lifetemp Sensor (temperature monitoring).

Figure 3 The Nonin3150 WristOx (pulse oximetry monitoring) and the blood pressure monitors.).

Table 2 Standardized questionnaire given to volunteers after monitoring.

	Questions
1	Did you find it easy to connect and use the devices?
2	Has the use of the device affected your daily life activities?
3	Has the use of the device affected the quality of your sleep?
4	Would you feel safer being discharged on the day of surgery if you were under monitoring?
5	Did you have difficulties with the adhesion of the devices to your skin?
6	Did any of the devices come off during monitoring? If yes, which one?
7	Have you had any allergic reaction to the devices (itching, rash)?
8	Did you have to improve the skin adhesion of the devices (e.g. shaving the area)?
9	What feature of the devices would you change?
10	Do you think the data on the screen should be visible or hidden?
11	How many days would you be willing to use this device?
12	Would you be comfortable with a video call with the medical team?
13	Would you be comfortable sharing photos with the medical team?
14	Would you authorize the recording of your data in your medical chart?

Results

In this study twenty healthy volunteers used RPM, which recorded their vital signs (non-invasive blood pressure, pulse oximetry, skin temperature, respiratory rate, heart rate and continuous electrocardiography) for a mean duration of 15.2 hours. The statistical results of these data are shown in Table 3. The sensor responsible for the heart monitoring was the most reliable in data transfer.

Table 3 Statistical results of vital signs recorded.

	Average	Median	Minimum	Maximum	Standard Deviation
Heart rate	61.25	59.00	44.00	92.00	7.14
Respiratory rate	14.06	14.00	7.00	22.00	2.46
SpO_2	95.65	96.00	94.00	100.00	0.91
Temperature	35.45	35.70	33.20	36.70	0.89
Systolic Blood Pressure	109.61	108.00	91.00	127.00	9.11
Diastolic Blood Pressure	72.09	72.00	62.00	82.00	4.99
Early Warning Score	0.87	0.00	0.00	5.00	1.16

Lifetemp sensor gave unreliable data in 80% of volunteers with an unreal hypothermia of 33°C during its usage.

WristOx, given its easily misplacement during sleep, had, on average, 36 minutes per volunteer without transmitting data during sleep.

The questionnaire was answered by 17 patients (85%). Most volunteers (70%) felt that connecting and using the devices was achieved without great effort. Regarding activities of daily living, 40% of volunteers did not notice any impairment and 20% reported that their activities were significantly affected. 60% of subjects reported no change in sleep quality, and 10% reported significant sleep disturbance from using the devices.

50% of volunteers mentioned difficulty adhering the device to the skin, and in 25% had the temperature sensor come loose. Two subjects had pruritus on the finger of pulse oximetry, one subject had a rash with the electrocardiography monitoring and one subject had pruritus with the electrocardiography monitoring. When asked if they would change anything about the equipment, two subjects mentioned interference with sleep at night from the LED lighting of the devices. When asked if the data collected should be visible to patients on the tablet, 50% answered they would prefer not to have access to the data.

Half of the subjects would be willing to use the device for up to two days and 20% for up to four days. Only two subjects (10%) declared that they would use the device just for one day.

88% of volunteers would agree to video chat with the medical team if needed. 94% would agree to share photos with the medical team if needed. 94% of volunteers would approve the transfer of collected data to the patient computer archive. 94% of subjects revealed that, in a postoperative setting, they would feel safer being submitted to day-case surgery if they were under monitoring after discharge.

Discussion

RPM is a technology that will increasingly be part of clinical practice in the future and will play an important role in the quality of life of patients in the immediate postoperative period on an outpatient basis. Although there are not a lot of studies about the reliability of RPM in the perioperative setting, some studies begin to reveal the potential of RPM in surgeries such as spine surgery (8) and colorectal surgery (9).

Data is transmitted wirelessly from the sensors to the patient gateway and from the patient gateway to a central server where it is stored for analysis. The PSE can notify medical staff when physiological data is outside the predefined limits for vital signs (Early Warning Scores), allowing to quickly and confidently detect deterioration after surgery, enabling early proactive intervention. The valuable data provided by the PSE also gives care teams the confidence to discharge patients sooner, leading to a faster recovery. The unobtrusive wearable sensors allow free movement and avoid bed confinement, which is much more comfortable for patients and allows patients to ambulate (walk), also minimizing risks for deep venous thrombosis. Wireless sensors reduce motion artifacts and overcome data loss due to cable detachment.

The temperature monitoring was feeble, because the device came off many times and we have registered low temperatures in most patients, knowing that it does not correspond to the real body temperature, but to what extent does it make sense to monitor temperature in postoperative patients? Maybe it could be useful in a possible case of infection, but in that case, we would not have a temperature change until probably the 3rd post op day when we would no longer have the patient monitored. It is our opinion that the use of a single sensor for temperature monitoring is not justified, as it does not add such valuable data and increases the cost of telemonitoring immensely.

The pulse oximetry monitoring is probably the most important tool in the postoperative setting, as respiratory depression can be a serious postoperative complication, especially in patients with undiagnosed sleep apnoea. Apart from being reliable and easy to use, the pulse oximetry can have repercussions in daily life activities as it is not very comfortable to use.

Cardiac monitoring provided heart rate data, continuous electrocardiography and blood pressure that was reliable. Cardiovascular complications, such as hypotension, hypertension and dysrhythmias, are very common in the postoperative setting, mainly due to side effects of the drugs used during anesthesia and past cardiac history of the patients such as coronary artery disease and heart failure. Taking this into account, heart monitoring is essential after surgery and overall it was easy to use.

Currently, thanks to the evolution of technology, many patients with hypertension have a home blood pressure measuring device and know how to use it. The blood pressure monitor used in telemonitoring is similar to the ones you can buy at the pharmacy, so they are easy and intuitive to use. However, it implies that the patient actively takes their measurement, so we will have very little data regarding this monitoring if patients are unable or unwilling to actively look for that assessment. Also during the night period when the patient is sleeping there will be no data regarding blood pressure, unless the device is programmable. The ideal would therefore be a wearable monitor that can be used 24 hours a day that would assess blood pressure.

Despite the clear benefits of telemonitoring, there are other data that unfortunately are not yet possible to monitor. Parameters such as pain and postoperative nausea and vomiting would be crucial, since these are the most frequent complications and bring great discomfort to patients (10,11). How could it be accomplished? Our suggestion is to

take advantage of the tablet, with a function that allows the patient to provide their level of pain and postoperative nausea and vomiting on visual scales, through a simple click on the screen.

Interaction with the tablet is also a concern. To what extent are elderly patients or patients with some cognitive deficit able to understand the importance of keeping a tablet for monitoring? The applicability of this type of monitoring is mainly in patients operated on an outpatient basis, and one of the criteria for this surgical regimen is the close surveillance of responsible adult in the first twenty-four hours. Therefore, it can be assumed that the responsible adult will also have access and interact with the tablet.

Another issue that is pertinent to ask is how and when the tablet and reusable devices will be returned to the department. Many strategies can be developed but that will always be a burdensome process.

How can we make technology more wearable? Perhaps in the future we will use the patient's smartwatch, the oximeter into a small, more practical sensor and the blood pressure meter into a wearable device.

What is disposable and what is reusable? In fact, both the oximeter and the blood pressure monitor are reusable, with the main consumable being batteries. At the end of each use, these sensors will be returned together with the tablet, properly sanitized and ready to be used on another patient. The temperature monitoring does not seem to be a crucial sensor in the telemonitoring of the patient, so, from the outset, it is possible to reduce costs. Therefore, the associated costs will be the acquisition of tablets and blood pressure monitors and oximeters, followed by the acquisition of heart and respiratory rate sensors, which are disposable at the end of monitoring each patient.

In what situations does the benefit outweigh the cost? How can investing in this type of equipment be beneficial for an institution? We are witnessing a transformation of conventional surgery into outpatient surgery, in an attempt to reduce hospital costs with hospitalizations. However, certain procedures can make the team uncomfortable as there is no close monitoring of patients postoperatively. Although the 24-hour postdischarge telephone follow-up improves patients satisfaction and is an appropriate tool to address patient's postoperative complaints (12), some reassessment of vital signs is needed to ensure a stable hemodynamic profile. It is in these patients that we believe that telemonitoring will bring more benefits in clinical practice compared to the associated costs.

Conclusion

RPM is not just about more data, but about having enough high-quality data to significantly improve the quality of care. Most of RPM's technologies today, when used properly over a continuous period of time, can provide a much higher level of quality data than previously. The key is to understand the ambulatory situations your patients are in and match them with the appropriate technologies and protocols.

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