The Surgical Company | CONNECTED CARE

Sensium®
Wireless Vitals Monitoring
INNOVATION BACKED BY EVIDENCE

Summaries and Abstracts from Sensium publications

	Title	Year	Journal
1	Perceptions on the Use of Wearable Sensors and Continuous Monitoring in Surgical Patients: Interview Study Among Surgical Staff	2022	JMIR Formative Research
2	Short-Term Wearable Sensors for In-Hospital Medical and Surgical Patients: Mixed Methods Analysis of Patient Perspectives	2021	JMIR Perioperative Medicine
3	Feasibility of continuous monitoring of vital signs in surgical patients on a general ward: an observational cohort study	2021	BMJ Open
4	Adaptive threshold-based alarm strategies for continuous vital signs monitoring	2021	Journal of Clinical Monitoring and Computing
5	Trial of remote continuous versus intermittent NEWS monitoring after major surgery (TRaCINg): a feasibility randomised controlled trial	2020	Pilot and Feasability Studies
6	2020 European Wearable Remote Patient Monitoring Technology Innovation Leadership Award	2020	N/A
7	Cost utility analysis of continuous and intermittent versus intermittent vital signs monitoring in patients admitted to surgical wards	2020	Journal of Medical Economics
8	Remote wireless vital signs monitoring on the ward for early detection of deteriorating patients: a case series	2020	International Journal of Nursing Studies
9	Postoperatives ‘‘remote monitoring’’	2019	Der Anaesthesist
10	Vital Signs Monitoring with Wearable Sensors in High-risk Surgical Patients: A Clinical Validation Study	2019	Anesthesiology
11	Are current wireless monitoring systems capable of detecting adverse events in high-risk surgical patients? A descriptive study	2019	Injury
12	Insights into postoperative respiration by using continuous wireless monitoring of respiratory rate on the postoperative ward: a cohort study	2019	Journal of Clinical Monitoring and Computing
13	Reliability of a wearable wireless patch for continuous remote monitoring of vital signs in patients recovering from major surgery	2019	BMJ Open

	Title	Year	Journal
14	Monitoring of High- and Intermediate-Risk Surgical Patients	2019	Anesthesia & Analgesia
15	Continuous versus intermittent vital signs monitoring in patients admitted to surgical wards: a cluster-randomised, controlled trial	2018	Journal of Medical Internet Research
16	Early diagnosis of acute respiratory failure using an E-health application in patients requiring oxygen therapy	2018	The American Journal of Emergency Medicine
17	Early diagnosis of atrial fibrillation using a E-health application	2018	www.sciencedirect.com/science/article/pii/S0735675718305436
18	Patient attitudes towards remote continuous vital signs monitoring on general surgery wards	2018	International Journal of Medical Informatics
19	Preliminary assessment of the SensiumVitals® System: a low- cost wireless solution for patient surveillance in the general wards	2015	35th Conference of the IEEE EMBS
20	Assessment of the feasibility of an ultra-low power, wireless digital patch for the continuous ambulatory monitoring of vital signs	2015	BMJ Open
21	Advances in Ultra-Low-Power Miniaturized Applications for Health Care and Sports	2013	Novel Advances in Microsystems Technologies and their Applications
22	Ultra-low-power semiconductors for wireless vital signs early warning systems	2011	Electronics Letters
23	Health-care electronics: The market, the challenges, the progress	2009	EDAA
24	Sensium: An Ultra-Low-Power Wireless Body Sensor Network Platform: Design & Application Challenges	2009	31st Annual International Conference of the IEEE EMBS
25	Energy Efficient Medium Access Protocol for Wireless Medical Body Area Sensor Networks	2008	IEEE Transactions on Biomedical Circuits and Systems, vol. 2, no. 4, December 2008
26	A 1 V Wireless Transceiver for an Ultra-Low-Power SoC for Biotelemetry Applications	2008	IEEE Journal of Solid-state Circuits
27	1V 14uW Switched-Opamp ADC for Bioelectric Data Acquisition	2007	Proceedings of the 4th IEEE-EMBS
28	Optimal Transmission Frequency for Ultralow-Power Short- Range Radio Links	2004	IEEE Transactions on Circuits and Systems —I: regular papers

1. Perceptions on the Use of Wearable Sensors and Continuous Monitoring in Surgical Patients: Interview Study Among Surgical Staff

Meera Joshi, PhD; Stephanie Archer, PhD; Abigail Morbi, MBBS; Hutan Ashrafian, PhD; Sonal Arora, PhD; Sadia Khan, DM; Graham Cooke, FRCP; Ara Darzi1, FRS
JMIR Formative Research, 2022

Summary

Background

Continuous vital sign monitoring by using wearable sensors may result in the earlier detection of patient deterioration and sepsis. Few studies have explored the perspectives of surgical team members on the use of such sensors in surgical patients.

Objective

This study aims to understand the views of surgical team members regarding novel wearable sensors for surgical patients.

Methods

Wearable sensors that monitor vital signs (heart rate, respiratory rate, and temperature) continuously were used by acute surgical patients. The opinions of surgical staff who were treating patients with these sensors were collated through in-depth semistructured interviews to thematic saturation. Interviews were audio recorded, transcribed, and analyzed via thematic analysis.

Results

A total of 48 interviews were performed with senior and junior surgeons and senior and junior nurses. The main themes of interest that emerged from the interviews were (1) problems with current monitoring, (2) the anticipated impact of wearables on patient safety, (3) the impact on staff, (4) the impact on patients overall, (5) potential new changes, and (6) the future and views on technology.

Sample quotes from staff on the recurring themes observed:

> *"We had a healthcare assistant who was agency, doesn't really work here much, where we thought things were up to date and when we went back to check, an observation hadn't been done, that patient had spiked [temperature], so obviously there's that time period in between we could have been acting sooner."*
> [Senior nurse #11]

> *"It gives us an idea of which patients we need to be looking at, more promptly, who we need to be directing the nurses to, who we need to be sort of escalating more quickly"*
> [Senior nurse #8]

> "*It's an element of probably giving people I suppose empowerment is quite a good word, but it gives them more confidence to make decisions."*
> [Senior surgeon #8]

Conclusions

Overall, the feedback from staff who were continuously monitoring surgical patients via wearable sensors was positive, and relatively few concerns were raised. Surgical staff members identify problems with current monitoring and anticipate that [Sensium] will both improve patient safety and be the future of monitoring.

Link:

https://formative.jmir.org/2022/2/e27866/

Status: Open Access.

2. Short-Term Wearable Sensors for In-Hospital Medical and Surgical Patients: Mixed Methods Analysis of Patient Perspectives

Joshi M, Archer S, Morbi A, Arora S, Kwasnicki R, Ashrafian H, Khan S, Cooke G, Darzi A.
JMIR Perioper Med 2021

Summary

Background and objective
Delayed detection of patient deterioration in hospitals is a major cause of morbidity and mortality and is mostly caused by human-related monitoring failure. Unfortunately, existing systems are unable to detect patient deterioration rapidly, and 39% of acute emergency patients admitted to critical care units are referred late. This study aimed to explore patient experiences with wearable sensor technology and carry out continuous monitoring through questionnaire and in-depth semi-structured interviews in an acute hospital setting.

Methods
Patients were recruited for a wearable sensor study and were asked to complete a 9-item questionnaire. Patients' responses were evaluated using a Likert scale and with continuous variables. A subgroup of surgical patients wearing a Sensium Vital Sign Sensor was invited to participate in semi structured interviews. The Sensium wearable sensor measures the vital signs: heart rate, respiratory rate, and temperature. All interview data were subjected to thematic analysis.

Results
Out of a total of 500 patients, 453 (90.6%) completed the questionnaire. Furthermore, 427 (85.4%) patients agreed that the wearable sensor was comfortable, 429 (85.8%) patients agreed to wear the patch again when in hospital, and 398 (79.6%) patients agreed to wear the patch at home. Overall, 12 surgical patients consented to the interviews. Five main themes of interest to patients emerged from the interviews: (1) centralized monitoring, (2) enhanced feelings of patient safety, (3) impact on nursing staff, (4) comfort and usability, and (5) future use and views on technology.

Central monitoring provided patients with greater peace of mind, and patients felt that health care staff were always around if a problem arose. Patients described feeling reassured knowing that they were being monitored even when health care staff were not at their bedside.

All interviewed patients commented on an enhanced feeling of patient safety while wearing the patch. "I felt like there was a second safety blanket around me, almost, and that I was constantly in amongst the nurses. I appreciate that the nurses do their obs as frequently as they can, but they're very busy. So, for this to be on constantly, it's reassuring," commented one patient.

All interviewed patients reported that wearable sensors and continuous monitoring would have an impact on the nursing staff. Most patients believed that these would ease the nursing workload who were already perceived to be under considerable strain.

Most patients in this study did not require extensive information before using the technology, reflecting the ease of use among patients. All interviewed patients described the patch as being comfortable to wear. Many patients had forgotten about the existence of the patch on their person once it was on.

The use of sensors for home-based monitoring was particularly important because patients expressed their current concern of going home after an operation and becoming unwell. Most patients would wear the wearable sensors again when in the hospital and at home. Patients had a very positive view of the sensor technology overall and felt that wearable sensors facilitating continuous monitoring would certainly be used in the future.

Conclusion
Overall, the feedback from patients was strongly positive. Wearable sensor technology continues to develop, and these data suggest that patients would welcome its use when acutely unwell and in an acute hospital setting.

Link:
https://periop.jmir.org/2021/1/e18836

3. Feasibility of continuous monitoring of vital signs in surgical patients on a general ward: an observational cohort study

Jobbe P L Leenen, Eline M Dijkman, Joris D van Dijk, Henderik L van Westreenen, Cor Kalkman, Lisette Schoonhoven, Gijsbert A Patijn, BMJ Open 2021

Summary

Background

The postoperative complication rate after major abdominal surgery is 20%–44%, which may result in reinterventions, prolonged hospital stay, intensive care unit (ICU) admissions and mortality, and eventually to lower life expectancy, lower quality of life and higher costs. Early detection of postoperative clinical deterioration on the ward may allow for early intervention and better outcomes. Emerging evidence shows that [wearable, wireless] monitoring sensors are accurate, may improve outcomes and reduce costs by allowing earlier detection of changes in vital signs in clinical practice.

Objective

The aim of the study was to determine the feasibility, in terms of acceptability and system fidelity, of continuous vital signs monitoring with the Sensium system, among abdominal surgery patients on a general surgery ward.

Methods

An observational cohort study was conducted for a 3-month period on one surgical ward of a large tertiary teaching hospital. Adult patients scheduled for elective colorectal or pancreatic resection were recruited through convenience sampling. In addition to standard care, patients included in the study were continuously monitored by the Sensium system.

Results

Thirty patients were monitored for a median duration hirty patients were monitored for a median duration of 81 hours. In terms of patient acceptability, twenty- seven patients returned the questionnaire. Of these, 25 patients (93%) rated wearing the patch as comfortable. Additionally, 18 patients (67%) agreed they felt safer during hospitalisation, and 8 patients (30%) were neutral about this statement. For a future admission in the

hospital, 24 patients (89%) would like to wear it and 20 patients (80%) would be willing to wear the patch for postsurgical

home monitoring. Patients stated that "'It provided a safe feeling for family also," and "I knew my limits through the system."

23 nurses returned the nurse questionnaire. Nurse satisfaction overall was mixed and 60.9% responded positive or neutral.

The system was found to be easily used and picked up. Out of the 23 nurses, 15 (65%) agreed they easily remembered how to use it and quickly became skilful with it (65%). The nurses perceived the ease of use favourably, for instance regarding the statement 'It is simple to use (73.5% positive response) and 'It is easy to use' (73.9% positive response).

Conclusion

Continuous monitoring of vital signs with a wearable device was very well accepted by patients. Nurses' ratings were highly variable, resulting in on average neutral attitude towards remote monitoring. The results suggest it is feasible to monitor vital signs continuously on general wards.

Link:
https://bmjopen.bmj.com/content/11/2/e042735

Status: Open Access.

4. Adaptive threshold-based alarm strategies for continuous vital signs monitoring

Rossum, M.C., Vlaskamp, L.B., Posthuma, L.M. et al. J Clin Monit Comput (2021).

Summary

Introduction

Continuous vital signs monitoring in post-surgical ward patients may support early detection of clinical deterioration, but novel alarm approaches are required to ensure timely notification of abnormalities and prevent alarm-fatigue.

Objective

This study evaluated the performance of classical and adaptive threshold-based alarm strategies for continuous vital signs monitoring in ward patients. The aim was to explore easy-to-implement and transparent methods to support identification of clinical deterioration related to postoperative AE's

Methods

The current study explored the performance of classical and various adaptive threshold-based alarm strategies to warn for vital sign abnormalities observed during development of an adverse event (AE). A classical threshold-based alarm strategy used for continuous vital signs monitoring in surgical ward patients was evaluated retrospectively. In the study, (combinations of) six methods to adapt alarm thresholds to personal or situational factors were simulated in the same dataset.

Alarm performance was assessed using the overall alarm rate and sensitivity to detect adverse events. Using wireless patch-based monitoring system, Sensium, 3999 h of vital signs data was obtained in 39 patients, over a period of 4 months.

Results

The results showed that the currently used classical threshold-based alarm strategy detected abnormalities in vital signs before or after onset of treatment in most of the observed AEs in ward patients.

The clinically used classical alarm system produced 0.49 alarms per patient/day with most alarms (63%) presented during daytime (8 a.m–10 p.m).

This study evaluated the performance of classical and adaptive threshold-based alarm strategies for continuous vital signs monitoring in ward patients. Each of the tested adaptive strategies either increased sensitivity to detect adverse events or reduced overall alarm rate. Combining specific alternative alarm strategies improved overall performance most, where sensitivity rates increased while raising only few extra alarms. In particular, the number of AEs where alarms were observed in the 24h prior to onset of treatment was increased, which suggests that implementation of multiple approaches to adaptive alarm thresholds may improve early detection of clinical deterioration in ward patients. Strategies that adapt vital sign alarm thresholds to personal or situational factors may improve early detection of adverse events or reduce alarm rates as compared to classical alarm strategies.

Conclusion

In conclusion, a classical threshold-based alarm strategy is able to identify abnormalities in continuously measured vital signs for the majority of AEs observed in surgical ward patients without causing excessive alarm rates.

Combining multiple adaptive threshold-based strategies may improving alarm performance and may contribute to increased or earlier identification of clinical deterioration.

Link:
https://link.springer.com/article/10.1007/s10877-021- 00666

Status: Open Access.

5. Trial of remote continuous versus intermittent NEWS monitoring after major surgery (TRaCINg): a feasibility randomised controlled trial

C. L. Downey, J. Croft, G. Ainsworth, H. Buckley, B. Shinkins, R. Randell, J. M. Brown, D. G. Jayne, November 2020

Summary

Background and introduction

Despite medical advances, major surgery remains high risk with up to 44% of patients experiencing postoperative complications. Early recognition of postoperative complications is crucial in reducing morbidity and preventing long-term disability. The current standard of care is intermittent manual vital signs monitoring, but new wearable remote monitors offer the benefits of continuous vital signs monitoring without limiting the patient's mobility.

The main aim of the study was to determine the feasibility of performing a large-scale individually randomised controlled trial of continuous remote monitoring after major surgery. Secondary aims were to informally assess the potential safety, potential efficacy, acceptability and potential cost utility of a wearable, remote monitoring system for patients after major surgery, as compared to standard monitoring with the NEWS system alone.

Methods

The study was a randomised, controlled, unblinded, parallel group, feasibility trial. Adult patients undergoing elective major surgery were randomly assigned to receive continuous remote monitoring and normal National Early Warning Score (NEWS) monitoring (intervention group) or normal NEWS monitoring alone (control group).

The study was conducted with 136 Patients, which were selected on the basis that they were undergoing elective major abdominal surgery.

Results

Most participants found the patch comfortable and felt safer wearing it. No formal comparisons between arms was undertaken; however, participants had fewer unplanned critical care admissions (1 versus 5) and had a shorter average length of hospital stay (11.6 days (95% confidence interval 9.5–13.7 days) versus 16.2 days (95% confidence interval 11.3–21.2 days)) in the continuous vital signs monitoring group.

A cost utility analysis indicated that the remote monitoring system was cost-saving when compared to standard NEWS monitoring alone. At the 6-week time horizon, the SensiumVitals® remote monitoring system was cost-saving when compared to standard NEWS monitoring from an NHS payer perspective.

The ICER was £1,460 (95% CI − £6,780, £9,701) per every one-point increase in overall quality of life on the abbreviated World Health Organization Quality of Life (WHOQOL-BREF) score. For the probabilistic sensitivity analysis, the results of the Monte-Carlo simulations are shown in the reference. This analysis indicates that the probability of cost-saving is 69.9% and the probability of benefit to quality of life is 58%.

Conclusion

It is feasible to perform a large-scale randomised controlled trial of continuous remote monitoring after major surgery. Progression to a definitive multicentre randomised controlled trial would be appropriate, taking consideration of factors, such as patient adherence, that might mask the potential benefit of additional monitoring.

Link:
https://pilotfeasibilitystudies.biomedcentral.com/articles/10.1186/s40814-020-00709-8

Status: Open Access.

6. 2020 European Wearable Remote Patient Monitoring Technology Innovation Leadership Award

Frost & Sullivan, November 2020

Summary

Background

Healthcare systems worldwide are trying to cope with an aging population and a rising number of patients suffering from long-term, chronic conditions. This puts burdens on healthcare systems, most of which occur due to adverse events. Moreover, disruptions to healthcare access is increasing due to the current pandemic, spurring the adoption of digital monitoring solutions that i.e. remotely collect and store biometric readings. These recent innovations in wireless and remote patient monitoring have shown promising evidence in improving patient outcomes. However, there is a lot of noise in the market and a lack of evidence-based publications on product efficacy and outcomes.

With its technical excellence, superior performance, and potential to significantly improve the standard of care, Sensium earns Frost & Sullivan's 2020 Technology Innovation Leadership Award in the European wearable remote patient monitoring market.

System performance and Evidence Base

The report notes that the Sensium system acts as a clinical early warning system for acute care; the System detects and notifies nurses and physicians on several, helping prevent the advent of hospital-based adverse events, the cost of which currently amounts to GBP 2.5 billion per year. Sensium differentiates itself from competitors due to the product's robust evidence base and real-word deployments.

Hospital @ Home service

The report noted the development of a Hospital@ Home solution, which will help hospitals reach beyond traditional infrastructure by providing oversight of managed home care providers, enabling additional capacity. The model is expected to yield significant growth to the company in the future.

Commercial model and cost savings

Frost & Sullivan notes that the Sensium System's ability to support early detection of any deterioration coupled with an outcome-centric approach leads to additional hospital capacity. Sensium leverages a technology-enabled care delivery model to decrease the cost of care to patients, payers, and providers. The company's innovative Sensium solution cost-effectively optimizes patient outcomes by supporting early intervention.

The Surgical Company - Connected Care's commercial model can be customized based on targets set by the hospitals. Recently the company has taken the route of value-based contracting by identifying and enabling providers' pain points through its product use. Remunerations are tied to hospital performance.

7. Cost utility analysis of continuous and intermittent versus intermittent vital signs monitoring in patients admitted to surgical wards

M. Javanbakht, A. Mashayekhi, M. Trevor, M. R. Hemami, C. Downey, M. Branagan-Harris, J. Atkinson

Abstract summary

Background

Complications after surgical procedures are common and can lead to a prolonged hospital stay, increased rates of postoperative hospital readmission, and increased mortality. Monitoring vital signs is an effective way to identify patients who are experiencing a deterioration in health. Sensium is a wireless system that includes a lightweight, digital patch that monitors vital signs at two-minute intervals, and has shown promise in the early identification of patients at high risk of deterioration.

Objective

To evaluate the cost-utility of continuous monitoring of vital signs with Sensium in addition to intermittent monitoring compared to the usual care of patients admitted to surgical wards.

Methods

A de novo decision-analytic model, based on current treatment pathways, was developed to estimate the costs and outcomes. Results from randomised clinical trials and national standard sources were used to inform the model. Costs were estimated from the NHS and PSS perspective. Deterministic and probabilistic sensitivity analyses (PSA) were conducted to explore uncertainty surrounding input parameters.

Results

Over a 30-day time horizon, intermittent monitoring in addition to continuous monitoring of vital signs with SensiumVitals was less costly than intermittent vital signs monitoring alone. The total cost per patient was £6,329 versus £5,863 for the comparator and intervention groups respectively. Each Sensium patched patient represents a potential cost saving of £466.

By utilising Sensium a typical 30 bedded ward expecting to treat 1500 patients would see savings in the region of £700K per year. Cost savings are driven by reduced costs of hospital readmissions and length of stays in hospital.

Conclusions

Use of Sensium as a postoperative intervention for patients on surgical wards is a cost-saving and cost- effective strategy, yielding improvements in recovery with decreased health resource use.

Link:

https://www.tandfonline.com/doi/full/10.1080/13696998.2020.1747474

Status:

Open Access

8. Remote wireless vital signs monitoring on the ward for early detection of deteriorating patients: a case series

L.M. Posthuma, C. Downey, M.J. Visscher, D.A. Ghazali, M. Joshi, H. Ashrafian, S. Khan, A. Darzi, J. Goldstone , B. Preckel. International Journal of Nursing Studies, January 2019

Abstract summary

Introduction

Remote wireless monitoring is a new technology that allows the continuous recording of ward patients' vital signs, supporting nurses by measuring vital signs frequently and accurately. A case series is presented to illustrate how these systems might contribute to improved patient surveillance.

Methods and results

Clinicians from five European hospitals including AMC, Amsterdam, Bichat, Paris, UCLH and Imperial college, London and St James's, Leeds reported cases using a remote wireless vital signs monitoring system on medical or surgical wards. Heart rate, respiratory rate and temperature were measured by the system every 2 min.

Nine cases tudies from across the five hospitals are presented. Four cases of (paroxysmal) atrial fibrillation are presented, two cases of sepsis and one case each of pyrexia, cardiogenic pulmonary edema and pulmonary embolisms.

All cases show that the remote monitoring system revealed the first signs of ventilatory and circulatory deterioration before a change in the trends of the respective values became obvious by manual vital signs measurement.

Discussion

This case series illustrates that a wireless remote vital signs monitoring system on medical and surgical wards has the potential to reduce time to detect deteriorating patients.

Link:

https://www.sciencedirect.com/science/article/abs/pii/S002074891930322

Status:

9. Postoperative ‘‘remote monitoring’’

Preckel B, Posthuma L, Visscher M, Hollmann M.
Der Anaesthesist. 2019;.

Abstract summary

During the course of surgical interventions, complications mostly occur in the postoperative period. On the normal ward, vital signs such as heart rate, respiratory rate and temperature are recorded every 4-8 hours. Even if the observations are every 2 hours and the collection of vital signs takes 10 minutes, the patient is only monitored for 120 min per 24 h and accordingly remains unobserved on the standard ward 22 of 24 h postoperatively.

The usual measurement of vital parameters by the nursing staff also possibly leads to a wake-up effect in the patient: Firstly by entering the room and collecting vital parameters, the patient is awakened. The respiratory rate increases, with possible changes in oxygen saturation. Secondly heart rate and blood pressure will often be elevated, compared to an unobserved period. This results in different readings than they had a few minutes before entering the room.

New wireless monitoring systems are available to continuously register some vital signs using a portable sensor and to identify any deviations in the form of alerts / alarms for the staff.

‘SensiumVitals® (Sensium Healthcare, Abingdon, UK) is a patch attached to 2 standard electrocardiogram electrodes that measures cardiac and respiratory rates and, using a sensor in the axilla, measures the patient’s body temperature. Granholm et al. [17] compared 3 methods of respiratory rate measurement: I. a standard method - an observer measures the respiratory rate at a random moment for 60 seconds in a patient who is breathing calmly during a 5-min period; II. Routine survey by the nursing staff and III. Using the SensiumVitals® wireless patch. For the respiratory rate, a reliable signal was registered only in 50% of the time points, which could be due to the highly sensitive measurement method of impedance pneumography, which is very sensitive to movement. At the times when a valid respiratory rate signal was measured, the agreement of the measured respiratory rate with the values obtained by standard measurement, apart from outliers, was acceptable [17]. However, the values of the respiratory rate obtained with the patch differed considerably from the routine measurements of the nursing staff.

Research has shown that routinely performed measurement of the vital parameters by the (nursing) staff is not always reliable. When registering the respiratory rate by the (nursing) staff, preference was given to the values 18, 20, 22 and 24, with 50% of the patients having a respiratory rate of 20 / min [3]. Also, in the previously cited work by Granholm et al. [17], a preference for respiratory rates 16, 18 and 20 / min was observed in routine measurements.

The correspondence of these measurements with the standard measurement methods described above (an observer measures the respiratory rate in a patient with calm breathing at an arbitrary moment for 60 s in a 5-min period) was correspondingly poor. Thus, it is not surprising that the routine measurements have a very poor agreement with the data obtained by the continuously measuring patch.

In another work, both the respiratory and heart rate, as measured by the SensiumVitals® sensor, were compared to standard monitor readings [20]. The mean deviation between the measurement methods was 1 heartbeat/min and less than 1 breath/min.

Link:

https://link.springer.com/article/10.1007%2Fs00101-019-00693-6

Status:

10. Vital Signs Monitoring with Wearable Sensors in High-risk Surgical Patients: A Clinical Validation Study

Breteler M, KleinJan E, Dohmen D, Leenen L, van Hillegersberg R, Ruurda J et al.
Anesthesia & Analgesia August 2019

Abstract summary

Background

Vital signs are usually recorded once every 8 h in patients at the hospital ward. Early signs of deterioration may therefore be missed. Wireless sensors have been developed that may capture patient deterioration earlier. The objective of this study was to determine whether two wearable patch sensors (SensiumVitals [Sensium Healthcare Ltd., United Kingdom] and HealthPatch [VitalConnect, United States]), a bed-based system (EarlySense [EarlySense Ltd., Israel]), and a patient-worn monitor (Masimo Radius-7 [Masimo Corporation, United States]) can reliably measure heart rate (HR) and respiratory rate (RR) continuously in patients recovering from major surgery.

Methods

In an observational method comparison study, HR and RR of high-risk surgical patients admitted to a step-down unit were simultaneously recorded with the devices under test and compared with an intensive care unit–grade monitoring system (XPREZZON [Spacelabs Healthcare, United States]) until transition to the ward. Outcome measures were 95% limits of agreement and bias. Clarke Error Grid analysis was performed to assess the ability to assist with correct treatment decisions. In addition, data loss and duration of data gaps were analyzed.

Results

Twenty-five high-risk surgical patients were included. More than 700 h of data were available for analysis. For HR, bias and limits of agreement were 1.0 (–6.3, 8.4), 1.3 (–0.5, 3.3), –1.4 (–5.1, 2.3), and –0.4 (–4.0, 3.1) for SensiumVitals, HealthPatch, EarlySense, and Masimo, respectively. For RR, these values were –0.8 (–7.4, 5.6), 0.4 (–3.9, 4.7), and 0.2 (–4.7, 4.4) respectively. HealthPatch overestimated RR, with a bias of 4.4 (limits: –4.4 to 13.3) breaths/minute. Data loss from wireless transmission varied from 13% (83 of 633 h) to 34% (122 of 360 h) for RR and 6% (47of 727 h) to 27% (182 of 664 h) for HR.

Conclusions

All sensors were highly accurate for HR. For RR, the EarlySense, SensiumVitals sensor, and Masimo Radius-7 were reasonably accurate for RR. The accuracy for RR of the HealthPatch sensor was outside acceptable limits. Trend monitoring with wearable sensors could be valuable to timely detect patient deterioration.

Link:

https://anesthesiology.pubs.asahq.org/article.aspx?articleid=2755691

Status:

11. Are current wireless monitoring systems capable of detecting adverse events in high-risk surgical patients? A descriptive study

Breteler M, KleinJan E, Numan L, Ruurda J, Van Hillegersberg R, Leenen L et al.
Injury, 2019

Abstract summary

Background

The objective of the study was to describe the ability of currently available wireless sensors to detect adverse events in high-risk patients.

Methods

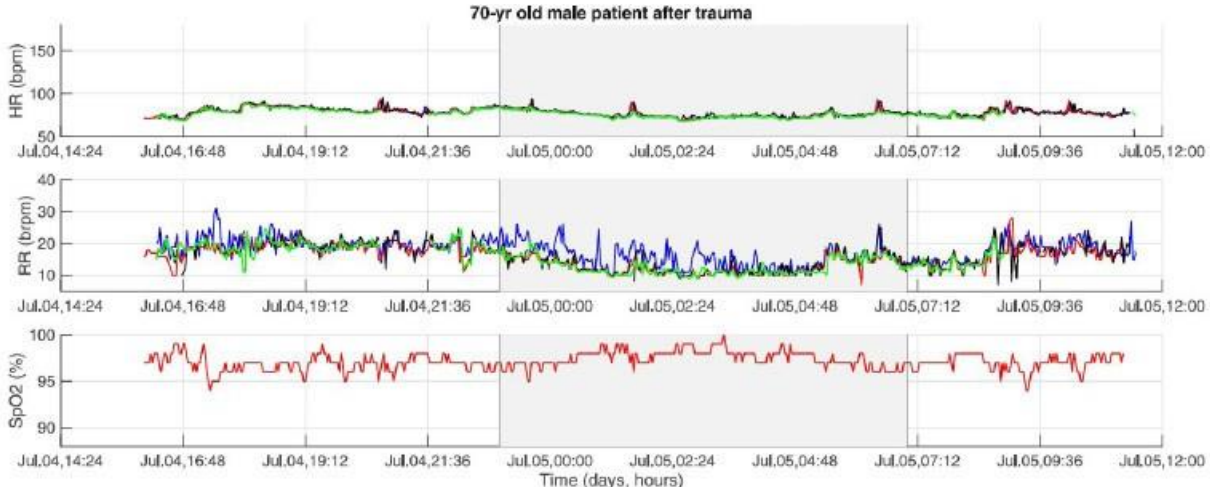
A descriptive analysis was performed of all vital signs trend data obtained during an observational comparison study of wearable sensors for vital signs monitoring in high-risk surgical patients during the initial days of recovery at a surgical step-down unit (SDU). Heart rate (HR), respiratory rate (RR) and oxygen saturation (SpO 2) were continuously recorded. Vital sign trend patterns of patients that developed adverse events were described and compared to vital sign recordings of patients without occurrence of adverse events. Two wearable patch sensors were used (SensiumVitals and HealthPatch), a bed-based mattress sensor (EarlySense) and a patient-worn monitor (Masimo Radius-7).

Results

Twenty adverse events occurred in 11 of the 31 patients included. Atrial fibrillation (AF) was most common (20%). The onset of AF was recognizable as a sudden increase in HR in all recordings, and all patients with new-onset AF after esophagectomy developed other postoperative complications. Patients who developed respiratory insufficiency showed an increase in RR and a decrease in SpO2, but an increase in HR was not always visible. In patients without adverse events, temporary periods of high HR and RR are observed as well, but these were transient and less frequent.

Conclusions

Current systems for remote wireless patient monitoring on the ward are capable of detecting abnormalities in vital sign patterns in patients who develop adverse events. Remote patient monitoring may have potential to improve patient safety by generating early warnings for deterioration to nursing staff.



Example of a patient in whom vital signs were recorded continuously on the surgical ward with the two wireless patch sensors (SensiumVitals: **black**, HealthPatch MD: blue), the bed-based system EarlySense (green) and a patient-worn monitor (Masimo Radius-7: red). The night from 11 p.m. to 7 a.m. is illustrated by shaded gray areas. No adverse events occurred during the measurement period.

Link:

https://www.injuryjournal.com/article/S0020-1383(19)30714-4/fulltext

Status:

12. Insights into postoperative respiration by using continuous wireless monitoring of respiratory rate on the postoperative ward: a cohort study

Posthuma L, Visscher M, Lirk P, van Dijkum E, Hollmann M, Preckel B. Journal of Clinical Monitoring and Computing. November 2019

Abstract summary

Introduction

This study aimed to evaluate feasibility of continuously measuring respiratory rate on the ward up to four days post-operatively using wireless monitoring equipment, without impeding mobilisation.

Method

Continuous monitoring of vital parameters using a wireless SensiumVitals® patch was installed and respiratory rate was measured every 2 mins. Feasibility of accurate respiratory rate monitoring was defined as valid respiratory rate measurements in at least 50% of time-points in more than 80% of patients during day- and night-time, respectively.

Results

Data from 119 patients was analysed. Results of the study showed that the patch detected valid respiratory rate measurements 75.2% of the time. During postoperative day and night four, the system still registered 68% and 78% valid measurements, respectively. 88% of the patients had more than 67% of valid respiratory rate measurements. The respiratory rates most frequently measured were 13–15; median respiratory rate was 15 (mean 16, 25th- and 75th percentile 13 and 19).

Discussion

The study demonstrated that it is feasible to measure electronically respiratory rate for up to four post-operative days in a surgical ward using a wireless monitoring system, allowing for patients to normally mobilize during the postoperative period and not producing sleep deteriorations: 88% of included patients had more than 67% of valid respiratory rate measurements.

Manually assessment of vital parameters might take up to 10 mins, meaning that even if vital functions are measured every 4 h (6 times a day), this will result in only 60 min of direct surveillance of the ward patient within 24 h, leaving the post-operative ward patient un-monitored for 96% of the time.

Taking vital parameters during night might add burden because of sleep deterioration and its consequences in the hospitalised patient [30]. Continuous wireless monitoring can help to dramatically reduce the interval for assessing vital parameters without affecting mobilization of the patient, or disturbing sleep.

Compared to standard registration of respiratory rate by counting 1 min of breathing, nurses only counted correct values in 3% of measurements if the actual respiratory rate of the patient was below 12/min. In contrast, nurses measured correct in 76% of times for respiratory values of 18–22 [34]. These data underline the necessity to improve respiratory rate measurement namely in those patients not breathing normally.

Link: https://link.springer.com/article/10.1007%2Fs10877-019-00419-4

Status:

13. Reliability of a wearable wireless patch for continuous remote monitoring of vital signs in patients recovering from major surgery

Downey C, Ng S, Jayne D, Wong D. 2019;9(8):e031150. BMJ Open

Abstract summary

This publication is a retrospective analysis comparing manually recorded vital sign data with data recorded by a remote vital sign monitor (Sensium Vitals) on a population of 51 patients. The main aim of the TRaCINg study was to determine the feasibility of performing a large-scale randomised controlled trial of continuous remote monitoring after major surgery. The primary outcome measure was 95% limits of agreement between manually recorded and wearable patch vital sign recordings of heart rate (HR), respiratory rate (RR) and temperature. Results concluded that there was a reasonable correlation between nurse observations and patch recordings for HR but a low correlation for RR and temperature.

Discussion

Respiratory rate findings

The study states that 'It is not clear whether there were errors in the manual observation, in the vital sign patch, or both.' The study also notes that distributions of RR in manually recorded measurements were clinically implausible. This is consistent with other research[1] that states 'Research has shown that routinely performed measurement of the vital parameters by the (nursing) staff is not always reliable. It is not surprising that the routine measurements have a very poor agreement with the data obtained by the continuously measuring patch.'

Other research[2] has evaluated Sensium RR in the context of the number of valid readings, finding valid reading 75% of the time (25% higher than the studies defined feasibility of adequate RR.) Temperature findings The paper comments that 'The high bias between the nurse-measured temperatures and the patch data can be explained by the difference in measurement techniques.' Sensium states that patch temperature is directly measured by an accurate (0.1 degree) temperature sensor placed in the axilla, and the measured value is directly reported. Manual observations are recorded using a tympanic thermometer, which uses an algorithm to estimate core temperature from the tympanic reading. The difference in measurement sites (axilla versus tympanic/core) will give an offset of up to 1 degree, although the axilla temperature should track changes/ trends in core temperature adequately [8], which equates with the findings of the study. The study highlighted some periods when Sensium reported "clinically implausible fluctuations of up to 2 degC within 2 hours". These fluctuations are due to the temperature sensor being only loosely situated in the axilla, causing the sensor to move out of place and essentially measure ambient/skin temperature. This misplacement can be due to incorrect attachment of the sensor, or may occur in patients who are very thin with hollow axilla (particularly the elderly).

Link:

https://bmjopen.bmj.com/content/9/8/e031150

Status:

1. Preckel B, Posthuma L, Visscher M, Hollmann M. Postoperatives „remote monitoring".
Der Anaesthesist. 2019;.
2. Posthuma L, Visscher M, Lirk P, van Dijkum E, Hollmann M, Preckel B. Insights into postoperative respiration by using continuous wireless monitoring of respiratory rate on the postoperative ward: a cohort study. Journal of Clinical Monitoring and Computing. 2019;.

14. Monitoring of High- and Intermediate-Risk Surgical Patients

Posthuma L, Visscher M, Hollmann M, Preckel B. Anesthesia & Analgesia October 2019

Abstract summary

The publication from the Department of Anesthesiology at Amsterdam University Medical Center, reviews elements of rapid response systems for recognising deteriorating patients on the ward and suggests possible further improvements for clinical settings. The publication states that 'Some systems measure vital signs accurately, like the SensiumVitals system (Sensium Healthcare, London, UK). This is a wireless patch measuring respiratory rate, heart rate, and temperature every 2 minutes.'

The review highlights that 'monitoring vital signs might improve early recognition of a deteriorating patient because adverse events (AEs) preceded by changes in vital signs in most patients'. Research reported a '5.7% incidence of AEs in hospitalized patients in the Netherlands. Forty percent of the AEs were preventable. More than half of these AEs were related to surgical procedures.'

It is recommended, although not often practiced, that 'vital signs/MEWS measurement takes place at least once every 6–12 hours on the ward'. Early Warning Scores have been introduced to highlight patients at risk for critical events when their vital signs are deranging from predetermined baseline/cut off scores. However 'timely and accurate monitoring of vital signs is a crucial first step in providing adequate input for EWS systems'. The review emphasises that changes in respiratory rate seem to be the most important predictor of clinical deterioration.

The publication defines remote wireless monitoring as 'technology whereby patients wear a non-invasive sensor that measures physiological variables' with the advantage being that vital signs are constantly measured. 'Wireless monitoring technology sometimes rejects data when, for instance, vital signs measurement is distorted due to severe motion artefacts. Hence, only accurate data is transferred to the caregivers. Accurate vital signs are available 50%–96% of the time, thus far more frequently than when vital signs are measured manually'.

Introducing remote monitoring technology requires significant implementation and the report highlights that 'caregivers need to realize that the system provides for a reduction in workload because vital signs monitoring is time consuming and stressful, particularly at night, when the nurse: patient ratio declines.'

The publication concludes that elements of rapid response systems need further improvement, and education and training are essential. 'Remote monitoring systems can support caregivers in the afferent arm of the system by measuring vital signs continuously and most importantly in an accurate manner.'

Link:

https://journals.lww.com/anesthesia-analgesia/Citation/2019/10000/Monitoring_ of_High and_Intermediate_Risk_ Surgical.44.aspx

Status:

15. Continuous versus intermittent vital signs monitoring in patient admitted to surgical wards: a cluster-randomised, controlled trial

C. Downey, R. Randell, J. Brown, D. Jayne Journal of Medical Internet Research December 2018 20(12):e10802

Abstract summary

Aims:

Vital signs monitoring is a universal tool for the detection of postoperative complications, but unwell patients can be missed in between traditional observation rounds. New remote monitoring technologies promise to convey the benefits of continuous monitoring to patients on general wards. The aim of this study was to evaluate whether continuous remote vital signs monitoring is a practical, acceptable and effective way of monitoring surgical patients.

Methods:

A cluster-randomised, controlled study was performed. Patients admitted to two surgical wards at a large tertiary hospital received either continuous and intermittent vital signs monitoring, or intermittent monitoring alone. The primary outcome measure was time to administration of antibiotics in sepsis.
Secondary outcome measures included length of hospital stay, 30-day readmission rate, mortality and patient acceptability.

Results:

350 patients were recruited between January and June 2017. 140 patients received continuous remote monitoring and 210 received intermittent monitoring alone.

On average, patients receiving continuous monitoring:

- Administered antibiotics on averages six hours faster after evidence of sepsis
- Had a10% shorter average length of hospital stay
- Were on average 45% less likely to require readmission within 30 days of discharge

Patients found the monitoring device to be acceptable in terms of comfort and perceived an enhanced sense of safety.

Conclusions:

Remote continuous vital signs monitoring on surgical wards is practical and acceptable to patients. Large, well-controlled studies in high-risk populations are required to determine if the observed trends translate into a significant benefit for continuous over intermittent monitoring.

Link:

https://www.jmir.org/2018/12/e10802

Status:

Open access to published article

16. Early diagnosis of acute respiratory failure using an E-health application in patients requiring oxygen therapy

Ghazali D, Stephan O, Choquet C, Antoniol S, Casalino E.
The American Journal of Emergency Medicine. December 2018

Summary:

Usually, patients hospitalized for community-acquired pneumonia requiring oxygen therapy but without vital distress, are not monitored in an intensive or critical care unit after their visit to ED. This situation can be life- threatening, especially if patients are unable to call for help until the nurse arrives for scheduled surveillance.

In this case a 36 year old patient presented with hyperthermia. Following physical examination and thoracic radiography, a diagnosis of right lower lobe pneumonia was established. Laboratory tests showed white blood cell count of 14.7 · 109 L−1 (N: 4–10.109) and procalcitonin was 0.39 μg·L−1 indicating a bacterial infection. Treatment with systemic amoxicillin 1000 mg was started, three times per day for seven days.

The patient was monitored using Sensium® technology and manual nurse observations every 8 h. Three hours after he was admitted, the emergency physician received a Sensium® alert by E-mail indicating a sudden increase of RR from 22 min−1 to 51 min−1, HR from 75 to 157 bpm, and temperature from 38.0 to 39.5 °C. Clinical examination found a severe acute respiratory failure with severe sepsis. The patient had an increase in bronchial congestion. He was immediately admitted to the critical care unit. Because of early care due to the alarm signal, the patient quickly received reinforcement in oxygenation therapy without requiring mechanical ventilation and the treatment for the sepsis resulting from pneumonia. His medical condition improved within only three days before going back to the medicine unit. The patient was discharged from the hospital after seven days.

The present case demonstrated how E-health technology using the Sensium® device might be helpful to early diagnose these clinical deteriorations by alerting doctors and nurses of early signs of acute respiratory
failure and sepsis which are RR and HR. Continuous vital signs monitoring outside the critical care setting is feasible and may provide a benefit in terms of improved patient outcomes and cost efficiency.

Link:

https://www.sciencedirect.com/science/article/abs/pii/S0735675718309823

Status:

17. Early diagnosis of atrial fibrillation using a E-health application

Aiham Daniel Ghazaliab, Christophe Choqueta, Enrique Casalinoac
The American Journal of Emergency Medicine June 2018

Summary:

A case report from the Emergency Department, University Hospital of Bichat, Paris, details the rapid diagnosis of a cardiogenic pulmonary edema in an elderly patient who was suffering from pneumonia and atrial fibrillation (AF).

The routine use of the Sensium System in this clinical setting allowed a timely clinical intervention and ensured that this patient avoided a potentially serious deterioration that could have led to a cardiac arrest.

Cardiac events occur relatively commonly in patients with acute community-acquired pneumonia. In the elderly, pneumonia can cause heart failure and is proven to be a trigger for AF.

In this particular Emergency Department, patients requiring oxygen for pneumonia are clinically monitored by nurses performing manual observations with a maximum frequency of three or four times per day. These patients are also continuously monitored using the Sensium System. With this wireless monitoring in place, the physicians are proactively notified of abnormal changes in patients' vital signs suggestive of patient deterioration.

The 82-year-old female patient presented with high temperature and tachypnea and was diagnosed with bacterial right lower lobe pneumonia. The patient was treated with oxygen therapy (2 l/min) and a respiratory rate of 18bpm was noted. The patient was monitored with manual observations at 8-hour intervals and also continuously monitored with the Sensium technology.

During the night shift Sensium notified of a sudden increase in heart rate and the following clinical examination found an abnormal left ventricular systolic function and arrhythmia, an electrocardiogram then confirmed a diagnosis of AF.

This case demonstrated that the Sensium System was effective as an aid to early diagnosis. The Sensium notifications and trends allowed the clinician to hypothesise the presence of AF in a context of pneumonia, and to use this information to rapidly diagnose a cardiogenic pulmonary edema.

The prompt treatment allowed the patient to avoid a potentially life-threatening deterioration that could have led to a cardiac arrest.

Link:

https://www.sciencedirect.com/science/article/pii/S0735675718305436

Status:

18. Patient attitudes towards remote continuous vital signs monitoring on general surgery wards: An interview study.

C.L. Downey, J.M. Brown, D.G. Jayne, R. Randell
International Journal of Medical Informatics Volume 114, June 2018, Pages 52-56

Background:

Vital signs monitoring is used to identify deteriorating patients in hospital. The most common tool for vital signs monitoring is an early warning score, although emerging technologies allow for remote, continuous patient monitoring. A number of reviews have examined the impact of continuous monitoring on patient outcomes, but little is known about the patient experience. This study aims to discover what patients think of monitoring in hospital, with a particular emphasis on intermittent early warning scores versus remote continuous monitoring, in order to inform future implementations of continuous monitoring technology.

Methods:

Semi-structured interviews were undertaken with 12 surgical inpatients as part of a study testing a remote continuous monitoring device. All patients were monitored with both an early warning score and the new device. Interviews were audio recorded, transcribed verbatim and analyzed using thematic analysis.

Findings:

Patients can see the value in remote, continuous monitoring, particularly overnight. However, patients appreciate the face-to-face aspect of early warning score monitoring as it allows for reassurance, social interaction, and gives them further opportunity to ask questions about their medical care.

Conclusions:

Early warning score systems are widely used to facilitate detection of the deteriorating patient. Continuous monitoring technologies may provide added reassurance. However, patients value personal contact with their healthcare professionals and remote monitoring should not replace this. We suggest that remote monitoring is best introduced in a phased manner, and initially as an adjunct to usual care, with careful consideration of the patient experience throughout.

Link:

https://www.sciencedirect.com/science/article/pii/S1386505618302508

Status:

19. Preliminary assessment of SensiumVitals: A low-cost wireless solution for patient surveillance in general wards

M. Hernandez-Silveira; K. Wieczorkowski-Rettinger; S. Ang; A. Burdett
2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC); 2015; pp.4931 - 4937

Abstract:

This paper presents SensiumVitals - an FDA cleared and CE marked wireless wearable vital signs monitoring system, developed for frequent surveillance of in-hospital patients. A number of in-house evaluations with artificial data and healthy volunteers were carried out in different stages to assess the reliability of two crucial vital signs

measured by the system - respiration and heart rate. In order to illustrate the potential of the system in hospital, a subset of data collected from acutely-ill patients during a separate clinical trial was also analyzed. In all cases the results revealed satisfactory agreement between the values reported by SensiumVitals and those recorded simultaneously by a clinically-approved bedside monitor. However, further work will be required to improve the reliability of the system under certain clinical conditions; which, although not crucial for our intended population (i.e. patients in general ward), pose interesting challenges for upgrading our technology for future use in these types of patients.

Link: http://ieeexplore.ieee.org/document/7319498/

Status:

20. Assessment of the feasibility of an ultra-low power, wireless digital patch for the continuous ambulatory monitoring of vital signs

Hernandez-Silveira M, Ahmed K, Ang S, et al BMJ Open 2015;5 :e006606. doi: 10.1136
bmjopen-2014-006606

Abstract:

Vital signs are usually recorded at 4–8 h intervals in hospital patients, and deterioration between measurements can have serious consequences. The primary study objective was to assess agreement between a new ultra-low power, wireless and wearable surveillance system for continuous ambulatory monitoring of vital signs and a widely used clinical vital signs

monitor. The secondary objective was to examine the system's ability to automatically identify and reject invalid physiological data. Overall agreement between digital patch and clinical monitor was satisfactory, as was the efficacy of the system for automatic rejection of invalid data. Wireless monitoring technologies, such as the one tested, may offer clinical value when implemented as part of wider hospital systems that integrate and support existing clinical protocols and workflows.

Link:
https://bmjopen.bmj.com/content/5/5/e006606

Status:

Open access

21. Advances in Ultra-Low-Power Miniaturized Applications for Health Care and Sports

M. Hernandez-Silveira; S. Ang; A. Burdett
Chapter 20 in Novel Advances in Microsystems Technologies and Their Applications; Part V Ultra Low Power Biomedical Systems; Editors L.A. Francis, K. Iniewski; CRC Press; July 2017; pp.463 -496

Abstract:

This chapter provides an overview of the Sensium technology health-care platform, with an emphasis on the development, evaluation, optimization and implementation of embedded biomedical algorithms suitable for body-worn devices. The engineering process leading to the ultimate incorporation of these algorithms into microchips is described, and trade-offs faced when implementing the software within limited hardware resources, without compromising the performance in terms of accuracy and reliability of the information, are discussed. In summary, this chapter provides an explanation of our methodology towards implementation of ultralow-power health-care platforms, focusing on the low power microchips and embedded software components.

Status:

22. Ultra-low-power semiconductors for wireless vital signs early warning systems

P. Soon-Shiong; C. Toumazou; A. Burdett
Electronics Letters; 2011; Volume: 47(26); pp. S26 - S28

Abstract:

Most patients in hospital have measurements of their ‘vital signs’ taken and recorded only intermittently, thus deterioration can occur to a point of serious consequence before it is recognised. New technologies are being developed which allow increased surveillance of patients` status without the inconvenience of being physically attached to immobile monitoring systems, and thus allowing patients to move around their rooms and floor areas. The implementation of a small, low- cost, ultra-low-power and disposable vital signs monitor is described, made possible by the development of a semiconductor SoC - Sensium - which implements all the required electronic functionality in a few square millimetres of silicon.

Link:
https://ieeexplore.ieee.org/document/6111653/

Status:

23. Health-care electronics: The market, the challenges, the progress

Wolfgang Eberle; Ashwin S. Mecheri; Thi Kim Thoa Nguyen; Georges Gielen; Raymond Campagnolo; Alison Burdett; Chris Toumazou; Bart Volckaerts
2009 Design, Automation & Test in Europe Conference & Exhibition; 2009; pp.1030 - 1034

Abstract:

Exploding health care demands and costs of aging and stressed populations necessitate the use of more in-home monitoring and personalized health care. Electronics hold great promise to improve the quality and reduce the cost of health care. The speakers in this hot topic session will discuss the field of health care electronics from all aspects. First, the market of health care electronics is described, and realities, trends and hypes will be pointed out.

The second presentation describes the engineering challenges in ultra-low-power disposable electronics for wireless body sensor applications. Both the sensor aspects, the related signal processing, and business models will be discussed. The third presentation talks about embedded bio-stimulation applications in cochlea implants, thereby highlighting the design challenges in terms of power consumption and extreme reliability of these devices.

The final presentation discusses the application of brain stimulation and recording with respect to artifact reduction and field steering, and describes aspects of the modeling and design strategy. In this way, this hot- topic session offers the attendees a complete picture of the field of health-care electronics, ranging from the business to the technological and design aspects.

Link:

http://ieeexplore.ieee.org/document/5090815/

Status:

24. Sensium: an ultra-low-power wireless body sensor network platform: Design & application challenges

A. C. W. Wong; D. McDonagh; O. Omeni; C. Nunn; M. Hernandez-Silveira; A. J. Burdett 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2009; pp. 6576 - 6579

Abstract:

This paper describes the Sensium system-on-chip for wireless body sensor networks, which integrates a transceiver, hardware MAC protocol, microprocessor, IO peripherals, memories, ADC and custom sensor interfaces. As well as addressing design challenges, this paper also discusses applications of this technology to body worn monitoring for real-time measurement of ECG, heart rate, physical activity, respiration and/or skin temperature. Two application challenges are described; the real-time measurement of energy expenditure using the LifePebble, and the development challenges surrounding the ‘Digital Patch’.

Link:

https://ieeexplore.ieee.org/document/5334001/

Status:

25. Energy Efficient Medium Access Protocol for Wireless Medical Body Area Sensor Networks

Okundu Omeni; Alan Chi Wai Wong; Alison J. Burdett; Christofer Toumazou
IEEE Transactions on Biomedical Circuits and Systems; 2008; Volume: 2(4); pp 251 - 259

Abstract:

This paper presents a novel energy-efficient MAC Protocol designed specifically for wireless body area sensor networks (WBASN) focused towards pervasive healthcare applications. Wireless body area networks consist of wireless sensor nodes attached to the human body to monitor vital signs such as body temperature, activity or heart-rate. The network adopts a master- slave architecture, where the body-worn slave node periodically sends sensor readings to a central master node. Unlike traditional peer-to-peer wireless sensor networks, the nodes in this biomedical WBASN are not deployed in an ad hoc fashion. Joining a network is centrally managed and all communications are single- hop. To reduce energy consumption, all the sensor nodes are in standby or sleep mode until the centrally assigned time slot. Once a node has joined a network, there is no possibility of collision within a cluster as all communication is initiated by the central node and is addressed uniquely to a slave node. To avoid collisions with nearby transmitters, a clear channel assessment algorithm based on standard listen-before-transmit (LBT) is used. To handle time slot overlaps, the novel concept of a wakeup fallback time is introduced. Using single- hop communication and centrally controlled sleep/ wakeup times leads to significant energy reductions for this application compared to more flexible network MAC protocols such as 802.11 or Zigbee. As duty cycle is reduced, the overall power consumption approaches the standby power. The protocol is implemented in hardware as part of the Sensium system-on-chip WBASN ASIC, in a 0.13- mum CMOS process.

Link:
https://ieeexplore.ieee.org/document/4668460/

Status:

26. A 1 V Wireless Transceiver for an Ultra-Low-Power SoC for Biotelemetry Applications

Alan Chi Wai Wong; Ganesh Kathiresan; Chung Kei Thomas Chan; Omar Eljamaly; Okundu Omeni; Declan McDonagh; Alison J. Burdett; Christofer Toumazou
IEEE Journal of Solid-State Circuits; 2008; Volume: 43(7), pp.1511 - 1521

Abstract:

This paper presents a 1 V RF transceiver for biotelemetry and wireless body sensor network (WBSN) applications, realized as part of an ultra low power system-on-chip (SoC), the Sensium. The transceiver utilizes FSK/GFSK modulation at a data rate of 50 kbit/s to provide wireless connectivity between target sensor nodes and a central base-station node in a single-hop star network topology operating in the 862-870 MHz European short-range- device (SRD) and the 902-928 MHz North American Industrial, Scientific & Medical (ISM) frequency bands. Controlled by a proprietary media access controller (MAC) which is hardware implemented on chip, the transceiver operates half-duplex, achieving -102 dBm receiver input sensitivity (for 1E-3 raw bit error rate) and up to -7 dBm transmitter output power through a single antenna port. It consumes 2.1 mA during receive and up to 2.6 mA during transmit from a 0.9 to 1.5 V supply. It is fabricated in a 0.13 mum CMOS technology and occupies 7 mm2 in a SoC die size of 4 times 4 mm2.

Link:
https://ieeexplore.ieee.org/document/4550651/

Status:

27. 1V 14uW Switched-Opamp ΔΣ- ADC for Bioelectric Data Acquisition

D. McDonagh; O. Eljamaly; A. J. Burdett
2007 4th IEEE/EMBS International Summer School and Symposium on Medical Devices and Biosensors; 2007; pp.147 - 150

Abstract:

In this paper, a 1 V DeltaSigma-ADC for bioelectric data acquisition is presented. Low power consumption is the major requirement in this design. Both the biquad low pass filter and the delta-sigma modulator are designed using switched-capacitors & switched-opamps. The low pass filter is used to limit the signal bandwidth to 100 Hz. The modulator is a 3rd order 1-bit topology. The sampling frequency and OSR are 32 kHz and 64 respectively. The digital filter is multi-stage & multi-rate to reduce power consumption. These circuits are a sub-part of a system-on-chip (SoC) for wireless body area sensor networks called the Sensiumtrade. The total area of the circuits is ~0.38 mm2. The ADC achieves 58 dB dynamic range (ENOB~9.6 bits) and consumes 14 uW of power.

Link:

https://ieeexplore.ieee.org/document/4338314/

Status:

28. Optimal transmission frequency for ultralow-power short- range radio links

D. C. Yates; A. S. Holmes; A. J. Burdett
IEEE Transactions on Circuits and Systems I:
Regular Papers; 2004; Volume: 51(7); pp. 1405
- 1413

Abstract:

Analysis determining the optimal transmission frequency for maximum power transfer across a short-range wireless link is introduced, including a comparison of near-field transmission with far-field transmission. A new near-field power transfer formula has been derived, which allows direct comparison with the well-known far-field Friis transmission formula. Operating charts are presented, which provide the designer with the preferred transmission frequency as a function of distance and antenna dimensions, together with surface plots which show the power transfer for this frequency. The analysis, performed for loop antennas, has been used to evaluate the oscillator transmitter as a low-power topology. It is shown that the requirement of a high-Q factor to realize a low-power oscillator need not be contradictory to achieving optimal far-field radiation characteristics. Based on this fact an approach to sizing loop antennas for low- power oscillator transmitters is suggested.

Link:

https://ieeexplore.ieee.org/document/1310511

Status:

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