British Journal of Anaesthesia **111** (6): 971–8 (2013)
Advance Access publication 21 August 2013 · doi:10.1093/bja/aet259

BJA

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Characterization of breathing patterns during patient-controlled opioid analgesia

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Editor's key points

- The authors have developed a system that uses accelerometers to measure and record respiratory movements.
- They also use recordings of nasal pressure to make inferences about respiratory air flow.
- Using these measurements, they have investigated respiratory patterns among patients receiving morphine via a patient-controlled analgesia system.

Background. Respiratory rate is an important measurement in patient care, but accurate measurement is often difficult. We have developed a simple non-invasive device to measure respiratory movements in clinical circumstances, with minimal interference with the patient. We investigated respiratory patterns in patients receiving postoperative morphine analgesia to assess the capacity of the device to detect abnormalities.

Methods. We studied subjects during self-administered opioid analgesia after major gynaecological surgery, and related the derived signals with a signal from a nasal cannula. Respiratory movement signals were transmitted wirelessly to a recorder from two encapsulated tri-axial accelerometer (RESpeck) sensors. We analysed the signals using two different sensor placements, each for 30 min. The nasal cannula signal was used to classify breathing patterns as obstructive or non-obstructed.

Results. We studied 20 patients for a mean duration of 49 min each. Breathing patterns were very variable, between and within patients. The median breathing rates ranged from 6.4 to 19.5 bpm. Breathing was partly obstructed in 10 patients, and six patients had repeated cycles of obstruction and transient recovery. In these patients, we found a consistent and statistically significant pattern of changes in chest wall movement, with increased abdominal and decreased rib cage movement during obstruction. In patients with slow respiratory rates, breath-to-breath times were highly variable.

Conclusions. In undisturbed subjects receiving patient-controlled morphine analgesia after surgery, abnormal breathing patterns are extremely common. Cyclical airway obstruction is frequent and associated with a typical pattern of changes in chest wall movement.

Keywords: monitoring, physiologic; respiration disorders; respiratory rate

Accepted for publication: 21 May 2013

Opioid analgesia is very often used after surgery, and the doses required after abdominal surgery commonly cause respiratory disturbances.[1 2] Breathing disturbances such as airway impairment that cause hypoventilation may be detected by pulse oximetry. However if oxygen therapy is used, as it is frequently, many episodes of obstruction are concealed.[3 4] Studies using more intensive methods such as continuous capnography have found very frequent adverse events.[5] Adequate monitoring to detect these events presents a substantial clinical challenge. Most currently used monitor systems require cannulae or connecting wires that can restrict patient movement and are easily displaced, the patient connections require careful supervision, and false alarms can be a substantial problem.[5 6] Although the pattern of chest wall movements after abdominal surgery and the changes that occur with obstruction are complex,[7] less invasive and more robust devices that can sense chest wall movements present an attractive alternative means of monitoring.[8]

We have developed a device, the RESpeck, which can be taped to a patient's body to detect respiratory movements and transmit the data wirelessly to a receiver in the ward. Preliminary studies showed that the signal could be consistently related to another measure of respiration, obtained from a nasal cannula.[9] Although consistent measurements of rate could be derived from the motion sensor, we were concerned that episodes of obstruction might not be detected. In the present study, we wished to characterize abnormalities of respiratory pattern, in particular those associated with respiratory obstruction, which could affect the measurement of the respiratory rate using chest wall movements, by observing patients after abdominal surgery.[1] We therefore used two montages of RESpeck sensors, compared with nasal cannula

recordings, to evaluate abnormal patterns of movement. We also observed abnormalities in respiratory timing.

Methods

We obtained permission from South East Scotland Regional Ethics committee to recruit patients about to undergo elective surgery. Subjects for elective major gynaecological surgery were seen at the preoperative assessment clinic, shown the device, and given information about the study. If they gave provisional consent, we then confirmed their wish to participate on the day of surgery. After surgery, patients were managed in a recovery area and given i.v. opioids (usually morphine) until comfortable. Patient-controlled analgesia (usually a dose of 1 mg morphine i.v., with a 5 min lockout) was started. The patients were studied after they had returned from the anaesthetic recovery area to the ward after surgery. The routine anaesthetic and surgical management of the patients was not affected by inclusion in the study. Those caring for the patients were aware of the study, but did not see the data collection, and care was taken to ensure that the recordings had as little effect as possible on routine practice. The usual variations found between patients, with regard to anaesthetic and surgical management, were those commonly present in routine practice in this surgical unit.

Data acquisition

Respiration

Breathing was measured using a nasal pressure cannula (SleepSense 14805-2-FT, S.L.P. Inc., Tel Aviv, Israel) placed at the subject's nose and secured round the ears in the same way as oxygen nasal cannulae. The cannula was connected via a bacterial filter to a small enclosure ($66 \times 66 \times 28$ mm) fastened to the subject's pillow containing a temperature compensated, calibrated pressure sensor (Freescale MP3V7007, Farnell, Leeds, UK) and a radio transmitter.

Chest wall movements

The RESpeck device contains a digital tri-axial accelerometer (MMA8451Q, Freescale, East Kilbride, Glasgow, UK), which internally samples data at either 12.5 or 50 Hz. The signal was filtered in software using a fourth-order Butterworth low-pass filter with a cut-off of 1 Hz. Data are transmitted using a 2.4 GHz transceiver (NRF24L01+, Nordic Semiconductor ASA, Skøyen, Olso, Norway). We used two RESpeck devices. The device is enclosed in a plastic capsule $45 \times 38 \times 13$ mm, and weighs 15.4 g (inset, Fig. 1). Each device was fastened inside a sealed plastic bag using double-sided adhesive tape. The bag was taped to the skin using a conforming, perforated polyester fabric tape with acrylic adhesive (Mefix, Mölnlycke Health Care Limited, Dunstable, UK) to hold the speck closely to the body surface. Using two successive positions for one of the sensors, we obtained two successive time periods of observation, with alternative sensor montages, which could be regarded to be detecting 'abdominal' and 'ribcage' paradoxical movement.

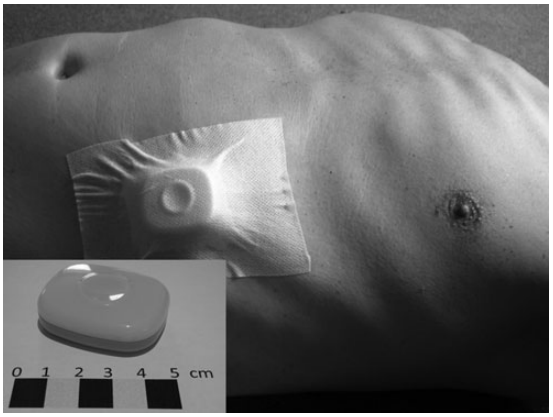

Fig 1 A RESpeck device, shown before attachment (inset) and attached using Mefix to the costal position (main photograph).

The orientation and pressure sensor signals were received by a base station with the above radio, and then by a USB serial link to a netbook computer. The movements of the surface of the body under the housing of the speck are detected as changes in inclination, relative to gravity, of three orthogonal axes. The axis and angle of the rotation between adjacent samples were used to compute a mean axis of rotation using a 30 s sliding window. The computer displayed the mean axis and pressure signals as they were acquired and allowed the observer to add a time-parallel record that noted events such as talking, coughing, and episodes of breathing disturbance.

The first sensor was attached to the upper quadrant of the abdomen, just inferior to the rib margin and in the midclavicular line. This position had been used in a previous study[9] and gave consistent results for respiratory rate measurements (Fig. 1). The sensor remained in place for the entire observation period of 1 h. The second sensor was first placed at the umbilicus, and after 30 min was moved to a position immediately caudal to the midpoint of the clavicle for a further 30 min of recording. Thus, we obtained data using two separate positions for the second sensor. The sensors and nasal cannula were then removed.

Data analysis

The nasal flow signal was first re-played alone, without a display of the motion sensor signals, using proprietary software (Spike 2, version 5.19, CED, Cambridge, UK). The patient breathing pattern was classified by an experienced observer who was unaware of the clinical identity or features of the patient. Limitation of inspiratory flow, indicating partial airway obstruction, was identified by a characteristic flattening of the waveform.[10] Each patient was first classified as either having evidence of obstruction or not. Patients considered to have airway obstruction were then classified into those who showed a cyclic pattern of increasing obstruction, followed by transient recovery, or those in whom the obstruction was not clearly cyclic. An example of the cyclic form of obstruction is shown in Figure 2 (note that only the nasal signal, and not the motion sensor signals, was used