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Accuracy of respiratory rate monitoring using a non-invasive acoustic method after general anaesthesia

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Editor's key points

- The RRa™ is a new acoustic monitoring device which can monitor respiratory rate.
- This study compared the RRa™ with capnometry in extubated patients after surgery.
- There was close correlation and reasonable limits of agreement between the two devices.

Background. Respiratory rate should be monitored continuously in the post-anaesthesia care unit (PACU) to avoid any delay in the detection of respiratory depression. Capnometry is the standard of care but in extubated patients requires a nasal cannula or a face mask that may be poorly tolerated or can be dislodged, leading to errors in data acquisition and false alarms. The value of a new non-invasive acoustic monitor in this setting has not been fully investigated.

Methods. Adult patients admitted to the PACU after general anaesthesia were included. After tracheal extubation, an adhesive sensor with an integrated acoustic transducer (RRa™) was placed on the patient's throat and connected to its monitor while the patient breathed through a face mask with a carbon dioxide sampling port (Capnomask™) connected to a capnometer. Both the acoustic monitor and the capnometer were connected to a computer to record one pair of data per second for up to 60 min.

Results. Fifty-two patients, mean (range) age 54 (22–84) yr and BMI 26 (19–39) kg m^{-2}, were studied. Compared with capnometry, the bias and limits of agreement of the acoustic method were 0 (−1.4–1.4) bpm. The acoustic sensor was well tolerated while the face mask was removed by eight patients, leading to study discontinuation in two patients.

Conclusions. In extubated patients, continuous assessment of respiration rate with an acoustic monitor correlated well with capnometry.

Keywords: capnometry; physiological monitoring; postoperative care; postoperative; complications; recovery room; respiratory depression

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Approximately 234 million major surgical procedures are performed worldwide each year. Respiratory depression is common during the early postoperative period, especially after extubation and when narcotic analgesics are required for pain management.[1] Delayed detection of respiratory depression increases the risk of death and major neurological sequelae. Therefore, continuous monitoring of arterial oxygen saturation (Sp_{O_2}) and respiration rate is recommended for all patients in the immediate period after general anaesthesia.[2]

Capnometry is the standard of care for continuously monitoring respiration rate in intubated patients. In extubated patients, end-tidal carbon dioxide concentration assessment requires a nasal cannula or a face mask that may be poorly tolerated or can move, inducing errors in data acquisition and false alarms.[3 4] A non-invasive respiratory monitoring device, using an adhesive sensor with an integrated acoustic transducer positioned on the patient's throat (Rad-87 Pulse CO-Oximeter with acoustic monitoring technology RRa™, Masimo Corp., Irvine, CA, USA), has been recently introduced. This device analyses respiratory vibrations to detect inspiratory and expiratory flow. The acoustic signal is then converted to continuous, numeric values of respiration rate.

The purpose of this study was to determine the accuracy of respiratory rate assessment by an acoustic method using RRa™ in extubated adult patients after scheduled surgery. Capnometry using a face mask (Capnomask™, GHW group, Meylan, France) was used as the reference method for measuring respiration rate because this method is as accurate as clinical measurement.[5]

Methods

This prospective study was conducted at the University Hospital of Poitiers, a 1000 acute care teaching hospital located in France. The study is registered at Eudract database

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(#2011-A00040-41). The local ethics committee approved the design of the study and informed consent was obtained from all patients. After general anaesthesia, adult patients admitted to the post-anaesthesia care unit (PACU) were included after extubation. Exclusion criteria were failure to tolerate an acoustic sensor or a face mask due to the presence of surgical sutures at points of contact with the device, requirement of non-invasive mechanical ventilation, pregnancy, and patients deprived of their liberty by court or administrative decision.

Patients were continuously monitored with electrocardiography, non-invasive blood pressure, and pulse oximetry per standard of care. An adhesive sensor with an integrated acoustic transducer (RRa™ rev C, Masimo Corp.) was applied to the patient's throat and connected to a specific monitor (Rad-87 Pulse CO-Oximeter, software version 7713, Masimo Corp.). According to the manufacturer's directions for use, the sensor was placed on either side of the larynx, above the thyroid cartilage and below the jaw line. Patients breathed via a size 3 or 4 Capnomask™ connected to a capnometer (Capnostream 20™, Oridion, Jerusalem, Israel) with a fixed oxygen flow rate of 6 litre min^{-1}. The Capnomask™ is a newly developed oxygen face mask with a $P_{E'CO_2}$ sampling line intended for use in spontaneously breathing patients. The Capnomask™ samples expired CO_2 from both the nose and the mouth, reducing the risk of false alarms. Both the acoustic monitor and the capnometer were connected to a computer for recording one pair of data per second for a maximum of 60 min, for subsequent analysis. The acoustic sensor or the face mask was repositioned when the signal was lost. For the acoustic monitor, the loss of signal is indicated by displaying double dashes instead of a number.

Episodes of apnoea, defined as an absence of chest wall movements lasting more than 10 s and determined by clinical observation, were recorded. Events that could interfere with measures (speaking, coughing, snoring, moving, sighing, vomiting, moaning, and repeated swallowing) were recorded and considered as impacting measurement accuracy of either device if a sudden change of at least 4 bpm for 10 s or more followed the occurrence of the event, without a concomitant change in the readings of the other device. Actual respiration rate was assessed clinically when the two monitors gave a difference of more than 4 bpm for at least 20 s.

Statistical analysis

Capnometry was regarded as the reference method of respiration rate assessment and the acoustic device as the method of comparison. Agreement between the reference method and the test method was assessed as described by Bland and Altman.[6] As unequal numbers of measurements per patient were collected, mean bias and limits of agreement were then adjusted and estimated by a component of variance technique.[6] Statistical analyses were performed with R software version 2.13.1 (R Development Core Team, Vienna, Austria).[7]

Results

A total of 52 patients were studied (Table 1). Patients were monitored for their respiration from 16 to 60 min providing a total of 99 002 pairs of respiratory rate measurements. Respiratory rates were easily assessed with both instrumental methods and ranged from 6 to 24 bpm. The acoustic sensor was well tolerated but required repositioning 13 times for loss of signal. The face mask was removed by eight patients, leading to study discontinuation for repeated removal in two of them.

The Bland–Altman plots for assessing respiration rate by the acoustic method are depicted in Figure 1. Compared with capnometry, the bias and limits of agreement were 0

Table 1 Patient characteristics, expressed as mean (range) or number

Male gender, *n*	25
Age (yr)	54 (22–84)
Body mass index (kg m^{-2})	26 (19–39)
ASA physical status, *n*	
I	14
II	28
III	10
Surgery type, *n*	
Gynaecological	11
Neurosurgical	6
Urological	8
Orthopaedic	7
Abdominal	12
Ear–nose–throat	3
Vascular	5

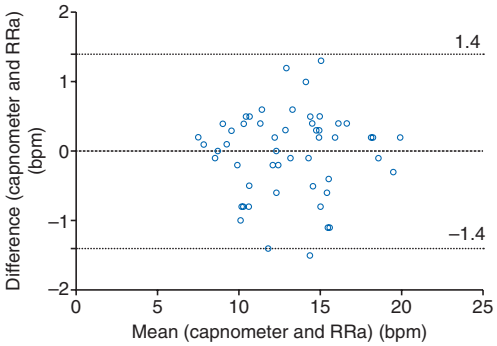

Fig 1 Graphic representation according to the Bland and Altman method of the bias and limits of agreement between the respiration rate obtained either by capnometry (Capnostream 20™, Oridion) using a face mask (Capnomask™, GHW group) or an acoustic device (Rad-87 with acoustic monitoring technology, RRa™, Masimo Corp.). Each point represents the bias of a single patient.

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