ORIGINAL ARTICLES

Continuous surveillance of oxygen saturation and respirations after bariatric surgery

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ABSTRACT

Background: Continuous, post-operative patient monitoring can provide healthcare workers with earlier warning signs of patient deterioration. The Masimo Pulse CO-Oximeter (Masimo Corporation, Irvine, CA) has acoustic monitoring technology which measures respiratory rate (RR) by analyzing acoustic signals generated across the upper airway while breathing. We continuously monitored for 19-24 hours (hrs) post-surgery RR and oxygen saturation (S_pO_2) in obese patients who underwent laparoscopic Roux-en-Y gastric bypass (RYGB) for bariatric surgery weight loss. The objective was to assess incidence of decreased RR (< 10 rpm), respiratory pauses and desaturation (< 90%) in a patient population that is at higher risk for hypoventilation, for an extended time after discharge from Post Anesthesia Care Unit (PACU).

Methods: After Institutional Review Board approval, 20 patients aged 18-65 with a body mass index (BMI) between 40 kg/m^2 and 60 kg/m^2 who received primary laparoscopic RYGB surgery by the same surgeon were enrolled in this study. After surgery, post-operative pain management included IV patient-controlled anesthesia dilaudid as an adjunct to intraoperative lidocaine infusions (see reference 3). We recorded Visual Analogue Scale (VAS) scores every 3 hrs for 24 hrs. RR and S_pO_2 were continuously monitored from the time of PACU arrival and for the following 19-24 hrs. The S_pO_2 alarm was set at 90% and respiratory pause alarm was set at 30 seconds to ensure a rapid response. Floor nurses were alerted immediately when these values were reached. Collected data for S_pO_2 and RR were graphed versus time for the 24-hr period for each patient in order to evaluate the incidence of low values. The data were then graphed versus time to yield a representation of cumulative time spent at each S_pO_2 level or respiratory rate. The data were stratified into two ranges for S_pO_2 ($S_pO_2 \geq 90\%$ and < 90%) and three ranges for RR (RR > 30, between 30 and 10, and < 10 breaths per minute). The percentage of time that the patient spent in each range was calculated. Median values were calculated for each category.

Results: During the extended monitoring period, the median percentage of time spent with S_pO_2 below 90% was 5.4%. The median percentage of time that a subject had a RR of less than 10 respirations/min was 0%. There was no correlation between S_pO_2 and respiratory rate. Fourteen patients in our study population were on continuous positive airway pressure (CPAP) and reported VAS scores between 3 and 6. This may have prevented them from being deeply sedated. There were no apnea periods longer than 30 seconds.

Conclusions: In this small group of obese patients, a low RR was not encountered during an extended post-operative period. These patients did not experience desaturation, apnea, or significant reductions of RR.

Key Words: Extended respiratory monitoring after bariatric surgery, Respiratory rate, Finger saturation

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1. Introduction

Continuous, post-operative patient monitoring is necessary in order to alert healthcare providers of warning signs of respiratory insufficiency post-surgically. This is particularly important in obese patients who are at high-risk of respiratory depression and hemodynamic compromise with opioid use.[1] Studying untoward and unexpected respiratory arrests is complicated because these occurrences are rare and oxygen saturation (S_pO_2) values recorded periodically in patient charts may underestimate severity of postoperative hypoxemia because of standard practices (i.e. waking up a patient and telling them to breathe deeply if S_pO_2 levels are low).[2]

The Masimo Pulse CO-Oximeter (Masimo Corporation, Irvine, CA) uses acoustic monitoring technology to measure respiratory rate (RR) by analyzing acoustic signals generated across the upper airway during turbulent flow with breathing. The software acquires and stores continuous SO_2 saturation and RR for several hours (hrs).[1] As an additional safety measure for a randomized drug trial, we continuously monitored and recorded RR and S_pO_2 in patients who underwent laparoscopic Roux-en-Y gastric bypass (RYGB), starting from time of admission to Post Anesthesia Care Unit (PACU) using the Masimo Radical 7 Pulse CO-Oximeter. The secondary objective was to assess incidence of decreased RR (< 10 rpm), respiratory pauses and desaturation (< 90%) in a patient population that was at higher risk for respiratory distress.

2. Materials & methods

The study was approved by the University of South Florida's Institutional Review Board and all patients provided informed consent. Some of this cohort was used in a previous study to evaluate the efficacy of intraoperative lidocaine infusion or placebo for post-operative pain management.[3] Though 10 patients were given lidocaine while under anesthesia and 10 were in the control group and given saline, we analyzed data collectively since the effects of lidocaine dissipated 3 hrs post-operatively.[3]

In order to measure respiratory effects, we continuously monitored and recorded S_pO_2 and respirations post-surgery using the Masimo Radical 7 Pulse CO-Oximeter. RR and S_pO_2 heart rate were continuously monitored and collected from the time of PACU arrival and for the following 24 hrs. The pulse-oximetry was set with an S_pO_2 alarm setting at 90% and a respiratory pause alarm at 30 seconds to ensure rapid response. Data for S_pO_2 and RR were graphed versus time for approximately 24-hr period for each patient (see Figure 1A and 1B). Outlying data points were investigated, identified as appropriate or artifacts, and artifacts due to motion or sensor displacement were removed from the dataset before analysis. This yielded several thousands of data points. A subset of data was extracted by averaging all data points over 5-minute intervals (to reduce the sheer volume of data and to create a dataset that was more manageable for statistical analysis). The data were then sorted from lowest to highest and graphed versus time to yield cumulative time spent at each S_pO_2 level or respiratory rate.

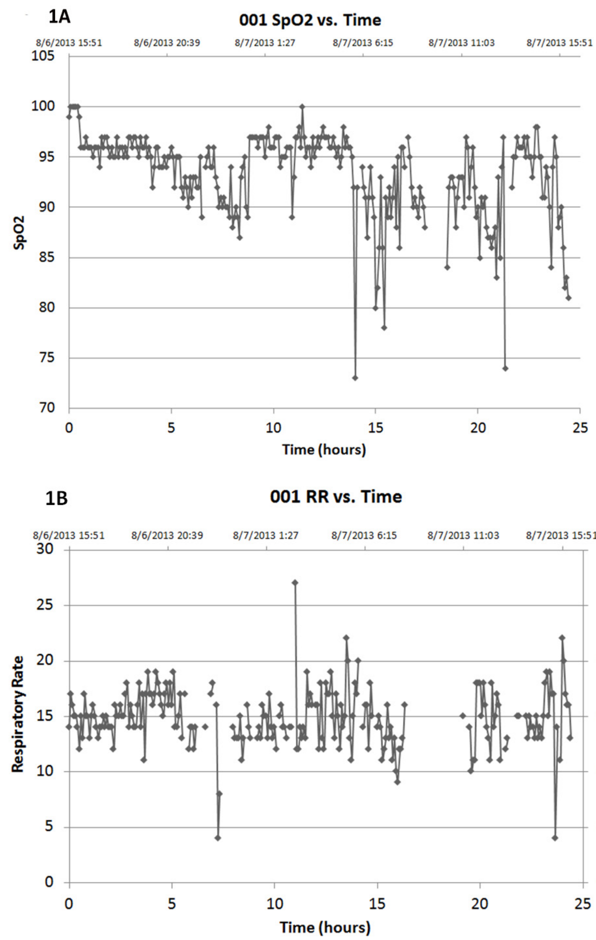

Figure 1. Representative data from Patient 001

Each data point represents the average value over a 5-minute epoch. Gaps in the graph represent time points during which the patient was disconnected from the machine (for example, to go to use the restroom, for therapy, or if the sensor contact to the skin was interrupted). (A) Averaged SpO2 value for each 5 minute epoch for 25 hrs postoperatively; (B) Averaged RR value for each 5-minute epoch for 25 hrs postoperatively.

The data were categorized into 2 ranges for S_pO_2 ($S_pO_2 \geq 90\%$ and $< 90\%$) and three ranges for RR (RR > 30, between 30 and 10, and < 10 breaths per minute). The percentage of time that the patient spent in each range was calculated by tallying the total number of 5-minute epochs that fell within the defined ranges and then dividing them by the total 5-minute epochs for that patient.

Our patient population was aged 18-65 with a body mass index (BMI) between 40 kg/m^2 and 60 kg/m^2. All patients received primary laparoscopic RYGB surgery by the same surgeon. Exclusion criteria for this study included patients who were pregnant; had history of chronic narcotic use, cirrhosis, portal hypertension, or extensive intraperitoneal adhesions; known allergies to lidocaine, hydromorphone, ketorolac, amide anesthetics, or corn; found to have abnormal serum potassium magnesium, alanine aminotransferase, or aspartate transaminase levels. Three patients had incomplete datasets because of disconnection of the sensor or loss of skin contact with pauses exceeding several hours. These patient data sets were excluded from the present analysis; thus, a total of 17 patient data sets were analyzed in this study. The available duration of data collection ranged from 19 hrs to 24 hrs.

3. Results

Complete data were collected on 17 subjects: they had an average BMI of 47.3 kg/mm^2, an average age of 47.4 years; 3 males and 14 females; 5 patients had a history of asthma; 13 had a history of sleep apnea, 12 patients used continuous positive airway pressure (CPAP) during the majority of the 24 hrs immediately following surgery as this was considered standard.

In total, we noted a median of 14 incidences (each incidence is the average over a 5-minute period) in which our patients experienced S_pO_2 of less than 90%. Of the total monitored time, 5.4% of the time was spent with S_pO_2 < 90%. The median number of incidences with $S_pO_2 \geq 90\%$ was recorded to be 228. This led to S_pO_2 being greater than or equal to 90% for 94.6% of the total monitored time. RR never fell below 10 breaths per minute; thus, the median percentage of total time monitored with a RR ≤ 10 was 0%. The median number of incidences with a RR between 10 and 30 was 234.0. The median for percentage of total time monitored with RR between 10 and 30 was 97.9. No incidences were recorded with an RR greater than or equal to 30; therefore, the percentage of total time monitored with RR greater than or equal to 30 was 0.0. Data are summarized in Table 1 and Table 2.

Separate analysis of the patients (9 in the lidocaine group and 8 in the placebo group) yielded similar results: the patients who received lidocaine infusion intraoperatively, showed 14.2% of total time with an SO_2 < 90%, and 85.8% of total pulses recorded were spent above an S_pO_2 of 90%. Moreover, 8.2% of total breaths recorded were spent below a RR of 10 bpm, 88% of total breaths recorded were spent between a RR between 10 bpm and 30 bpm, and 3.8% of total breaths recorded were spent above a RR of 30 bpm. Lapses in data monitoring were shorter than 20 minutes in duration; thus, we included all 17 patients in our data analysis. In all, the percentage of missing data is < 10% of total data collected.

Table 1. 20-24 hr continuous monitoring of S_pO_2 for 17 patients (all data points in a 5-minute time period are averaged to obtain the value for that 5-minute epoch)

	Median
Number of 5-minute Epochs with an average SpO_2 < 90%	14.0
Percentage of Total Monitored Time with an SpO_2 < 90%	5.4
Number of 5-minute Epochs with an average $SpO_2 \geq 90\%$	228.0
Percentage of Total Monitored Time with an $SpO_2 \geq 90\%$	94.6

Table 2. 20-24 hr continuous monitoring of RR for 17 patients (all data points in a 5-minute time period are averaged to obtain the value for that 5-minute epoch)

	Median
Number of Incidences with a RR $\leqslant$ 10	0.0
Percentage of Total Time Monitored with a RR $\leqslant$10	0.0
Number of 5-minute epoch with an RR between 10-30	234.0
Percentage of Total Time Monitored with RR between 10-30	97.9
# of 5-minute epochs with a RR $\geqslant$ 30	0.0
Percentage of Total Time Monitored with RR > 30	0.0

Note. RR: respiratory rate

Our previous publication details the immediate postoperative narcotic utilization which was slightly different for the group of patients receiving lidocaine and the group of patients receiving placebo; however, these differences are not statistically significant. On average for all the placebo patients, 12.6% of total pulses recorded were spent below an S_pO_2 of 90% and 87.3% of total pulses recorded were spent above an S_pO_2 of 90%. On average for all of the placebo patients, 6.6% of total breaths recorded were spent below a RR of 10 bpm, 93% of total breaths recorded were spent between a RR between 10 bpm and 30 bpm, and 0.4% of total breaths recorded were spent above a RR of 30 bpm. Therefore, we could not demonstrate a difference between the two patient groups (lidocaine vs. placebo).

4. Discussion

While it is known that RR is a sensitive indicator of respiratory problems, the best method for its continuous measurement is unclear.[4] Though clinically important, RR is the last vital sign that does not have a reliable continuous monitoring method that is easily tolerated.[4] In an acute study by Gaucher et al.,[4] comparing RR assessed by capnometry using a new oxygen mask and a carbon dioxide sampling port and thoracic impedance pneumography with clinical measurement in the extubated patients receiving supplemental oxygen, patients were studied only for 30 minute periods. During the study period, no episodes of apnea or arterial desaturation were observed, leading to the conclusion that monitoring postoperative RR by capnometry through an adapted oxygen mask in extubated patients was more accurate than by thoracic bioimpedance and could be a sufficient alternative to clinical assessment.[4,5]

Ramsay et al.[6] assessed a new acoustic ventilator rate monitoring technology for accuracy, precision reliability, and the ability to detect pauses in ventilation, with respect to capnometry as well as a reference method in postsurgical patients. The research was a short-term study that continuously monitored patient ventilator rate for an average of 112 minutes per patient in the PACU only.[6] Results showed that acoustic monitoring was more accurate than capnometry for monitoring ventilation rate. Over the course of monitoring, the researchers were able to determine periods of low RR and apnea. Ramsay et al.[6] did not record and analyze these factors associated with the loss of data or inaccurate readings; a larger study would be necessary to define these parameters. The presently used methods of monitoring are not accurate or well-tolerated by patients, thus, justifying the need for new technology. An acoustic transducer that can be integrated into an adhesive patch placed on the patient's neck may be a promising alternative to continuously monitoring respiratory rate.[6] This study illustrates that acoustic monitoring proves a very reliable, noninvasive, continuous method for approximating ventilator rate in post-surgical patients.[6]

Atkins et al.[7] studied how accurate the Masimo rainbow acoustic monitor was in instances of rapid transitions in respiratory rate. Visual inspection of the raw respiratory waveforms allowed for the exclusion of artifacts. Patients were monitored with Masimo rainbow acoustic monitor while under anesthesia with a laryngeal mask airway (LMA).[7] The study obtained data from 50 patients with a total recorded time of 1,416 minutes.[7] Respiratory acoustic monitoring (RRa) responded to a change in RR in approximately 45 seconds which is sufficient for detection of changes in respiration in the majority of clinical settings. Respiratory pauses were determined from continuous monitoring of breath sounds as well as with an independent algorithm for RR calculation. Atkins et al. did not evaluate the utility of the presence of RRa when an obstruction was seen with natural airways or the effects of certain behaviors (e.g. chewing, talking, or coughing).[7] When the patient was spontaneously ventilating under general anesthesia, RRa provides accurate approximations of respiratory changes over a broad range of respiratory rates. Still, it is important to note that erroneous values can be obtained under conditions of transient apnea, though these errors rarely last for longer than 30 seconds.[7]

Preventable patient deterioration and death after surgery is a high priority for a hospital. Continuous routine patient monitoring postoperatively provides healthcare providers with earlier warnings of patient deterioration.[2] In a study by Taenzer et al.,[2] researchers studied deterioration that occurs in general care settings where staff may be available to intervene; however, they are unaware of deterioration. This was accomplished via long-term monitoring using continuous pulse oximetry. The pulse oximeter was attached to a patient surveillance system (PSS) that alerted staff, via pager, to a patient's desaturation.[2] Alarm triggers were set for S_pO_2 below 80% and heart rate below 50 bpm or more than 140 bpm. The PSS was implemented in one ward and compared to two other control wards that did not use the PSS.[2] Results showed that early detection of physiologic parameter deterioration was correlated with the need for fewer rescue events and decreased need to escalate care. Patients readily accepted continuous monitoring via pulse oximetry.[2] Taenzer et al.[2] also tested other continuous monitoring systems such as carbon dioxide and respiratory rate; however, because several pilot studies with these measures found that patient tolerance and compliance are too low, they could not be used as continuous monitors in the wards.

Interestingly, our patients did not experience low respiratory rates. Higher VAS pain scores, ranging from 3 to 6, indicate patients were in moderate pain. This would prevent them from sleeping soundly and, thus, having lower respiratory rates. Additionally, because these patients were obese, CPAP was applied in a majority of the patients. This could have also prevented lower RR.

5. Conclusions

Our data are limited by a small sample size; however, we were able to effectively monitor a subset of patients that were on CPAP and had a higher risk for respiratory distress using the Masimo Radical 7.

Rainbow acoustic monitoring creates the opportunity to monitor RR in real-time and allows providers to monitor changes in RR over a wide range. Though misleading values can be recorded during transient episodes of apnea, errors do not normally persist for longer than 30 seconds. Thus, rainbow acoustic monitoring has tremendous clinical utility. At our institution, this method of monitoring has gained widespread acceptance and has allowed us to minimize respiratory arrest following surgery, especially in at-risk populations such as obese patients.

Conflicts of Interest Disclosure

The authors have no conflicts of interest to disclose.

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