Introduction
Continuous respiratory rate measurement could detect ventilation and oxygenation-related complications early before they result in cardiac arrest. Current methods to monitor patient’s respiratory rate include manual counting of breaths, impedance pneumography and capnography. All of them have limitations in terms of accuracy and patient tolerability. Recently, Masimo developed a bio-acoustic sensor (Rainbow Acoustic Monitoring, RAM, Masimo Corporation, Irvine, CA) that has FDA clearance and CE mark for use in adult patients over 30kg. In this multicenter, prospective study we evaluate the accuracy of RAM in pediatric, post anesthesia care unit (PACU) patients compared to capnography, the current standard of care.

Methods
After obtaining informed, parental consent, 26 pediatric PACU patients were enrolled: 11 from Cincinnati Children’s Hospital Medical Center, 8 from University of Arizona Medical Center, and 7 from Children’s Medical Center at Dallas. Respiration rate was measured by capnography (Capnostream 20 with sidestream nasal cannula, Oridion, Needham, MA) and acoustic monitoring (Rad-87, version 7.7.1.3 and 7.8.0.5, connected to an adhesive acoustic sensor, RRa, Rev C, Masimo, Irvine, CA). Acoustic sensors were placed on the patient’s neck for subjects over 2 years of age and to the chest for subjects under 2 years of age. The acoustic monitor and capnograph were connected to a computer for continuous waveform recording. The reference respiration rate was obtained by retrospective analysis of capnography and acoustic monitor waveform files by a trained respiratory therapist to confirm the presence of a breath. To assess performance, bias, precision and Arms (Accuracy Root Mean Square) of respiration rate measurements were calculated for RAM and capnograph compared to the reference method and scatter plots were generated.

Results
Respiration rate measurements were analyzed in 26 pediatric patients between the ages of 14 months and 14 years (average 7.6) with weight ranging from 10kg and 50kg (average 28kg). Sixteen patients weighed under 30 kg, and 10 patients a weighing 30 kg or greater. The average monitoring time was 98 min for RAM and 96 min for capnograph. RAM showed a bias, precision and Arms of -0.02, 3.25 and 3.25 breaths per minute (bpm) compared to the reference method, whereas capnograph showed a bias, precision and Arms of 0.23, 3.29 and 3.30 bpm.

Discussion
This multicenter study showed that respiratory rate measured from noninvasive, acoustic monitoring had similar accuracy and precision as nasal capnography, the current standard of care in pediatric patients.

Summary
Monitoring the respiratory rate of infants, children, and adolescents during perioperative care is critical for early detection of respiratory complications that alert the anesthesiologist for early interventions that avoid life-threatening events. Recently, Masimo developed a bio-acoustic sensor (Rainbow Acoustic Monitoring, RAM) that facilitates respiratory rate monitoring. In this multicenter study we found that respiratory rate measured from noninvasive, acoustic monitoring had similar accuracy and precision as nasal capnography, the current standard of care when used in pediatric patients.