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TITLE: CONTINUOUS AND ACCURATE END-TIDAL CO_2 AND ANESTHETIC CONCENTRATION MEASUREMENTS AT HIGH RESPIRATORY FREQUENCIES

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Continuous and accurate measurement of expired CO_2 and anesthetic agent concentrations at high (>60/min) respiratory frequencies (f) and low (<10 ml) tidal volumes (V_t) is theoretically possible using mass spectrometry[1], but has yet to be demonstrated in live subjects. The present study assesses the feasibility and accuracy of continuously measured respiratory gas concentrations at high f using a commonly available mass spectrometer.

Materials and Methods: Subjects for the present study were 15 male rats weighing 350-400 grams. Following induction of general anesthesia (halothane), animals were intubated and mechanically ventilated using a Harvard small animal ventilator with V_t = 10 ml/kg. A polyethylene catheter (PE-50) was inserted into the circuit with the tip distal to the y-connector. It was then connected to the continuous sampling (30 ml/min) catheter of an Ohmeda 6000 mass spectrometer. Arterial blood samples were collected from a tail artery cannula for measurement of P_aCO_2. In 5 animals f was varied from 35-80/min in order to examine the correlation between end-tidal CO_2 (E_tCO_2) and P_aCO_2. In 10 other animals f was varied (f=45-60/min) to maintain E_tCO_2 at 37±2 mmHg. Halothane MAC was measured in the latter group using the tail clamp method[2] and end-tidal halothane concentrations from the halothane capnogram. Temperature was maintained at 37±0.5°C in all animals. P_aCO_2 and E_tCO_2 were compared using linear regression analysis.

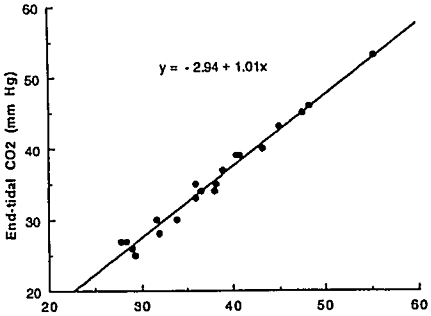

Fig 1

Results: There was no rebreathing or air leak in the system. CO_2 and halothane waveforms had relatively flat end-tidal plateaus until f exceeded 70/min. E_tCO_2 varied from 26 to 53 mmHg. There was excellent correlation (r^2=0.98) between E_tCO_2 and P_aCO_2 (Fig.1). At f=45-60/min, E_tCO_2 was 1-2 mmHg less than P_aCO_2, a normal arterial-alveolar CO_2 gradient. The gradient between E_tCO_2 and P_aCO_2 increased with increasing f, but was never greater than 4 mmHg (f=80/min). Halothane MAC was 0.94±0.03 vol%, in close agreement with a recent measurement of halothane MAC in rats[3].

Discussion: Mass spectrometry may be used to accurately and continuously measure expired gas concentrations in subjects requiring small V_t (3-4 ml) and high respiratory rates (f=35-80/min). Underestimation of E_tCO_2 remains small even when f=80/min. This system also provides a simple and accurate way to make MAC measurements in very small animals.

References

1. Anesth Analg 67:88406, 1988
2. Anesthesiology 40:52-57, 1974
3. Anesthesiology 73:93-99, 1990

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Analysis of the Task of Administering Anesthesia: Additional Objective Measures.

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Introduction: The anesthesiologist works in a complex environment in which the successful administration of anesthesia requires hundreds of manual and visual tasks. Objective analysis of the anesthesia task is necessary for understanding the factors which affect anesthetic vigilance and performance. We have previously described a simple methodology for performing real-time task and workload analysis in the OR [1, 2]. The purpose of the present study was to develop additional methods by which task patterns and workload levels could be objectively measured and evaluated.

Methods: After institutional approval, junior anesthesia residents performing cases of general endotracheal anesthesia (n=11) of 1-4 hr duration were studied. The activities of the anesthetist, resolved into 28 task categories, were recorded by a trained observer using an Apple Macintosh™ and a custom Hypercard™ program [1,2]. As previously described, the methodology involved 3 separate task probes: 1) Discrete Task Analysis; 2) Secondary Task Probing; and 3) Subjective Workload Assessment. We now report 3 additional, more advanced, techniques for examining the data obtained from Discrete Task Analysis: 1) Link Analysis; 2) Task Density Analysis; and 3) Rhythm Analysis. Link Analysis was performed to examine the frequency of links between all successive pairs of tasks. Task Density Analysis provided a means of measuring workload by calculating the number of tasks per unit time. Task Density data were then transformed using Fourier analysis to the detect the presence of task rhythmicity. These analyses were done on an IBM-compatible PC using custom software written in Quick Basic. Statistical differences were assessed using ANOVA and data are presented as mean ± SEM.

Results: Using Link Analysis (392 possible links), the average link rate (4.5±0.5 links/min) was greater in the induction period (from entry of the patient into the OR until successful intubation) than during the rest of the case (3.8±0.3 links/min). Over the entire case, the top 5 links represented 25.0% of the total (4463 total links). The most common links were 'Observing Monitors'-'Recording' (9.5%) and 'Observing Monitors'-'Conversing with Attending' (8.8%). The 5 most common links during induction were different than those during the rest of the case, and represented 27.2% of the total (945 total). The most common link during induction was 'Mask Ventilation'-'Observing Monitors' (13.1%). Task Density Analysis of discrete task data revealed that when the activity level was high, the average amount of time spent per task was low. Conversely, when activity level was low, the average amount of time spent per task was high. Rhythm analysis suggested appreciable periodicity in some cases. For example, in one case, there was a significant power peak at 100 sec, suggesting rhythmic increases in task density and workload.

Discussion: In this preliminary study, despite the small number of cases, the results suggest that these analysis techniques will prove valuable in objectively describing and understanding the anesthesia task. These techniques are being evaluated in the context of a larger study designed to investigate the effects of training and experience on task composition and workload. Residents will be followed and restudied at intervals over 3 years. Because, the present study only examined cases done by junior residents, the actual data obtained might not be generally applicable to all anesthetists. However, these data *are* comparable with previous task analyses [1-3]. Similar to the findings of others [3], recordkeeping encompassed 12% of the anesthetist's time while "direct patient care" consumed 25% of the time. The present study suggests that these 3 objective techniques of analyzing easily obtainable task data show great promise for further investigation of the nature of the anesthetic task and the factors that affect performance of the anesthetist in the complex OR environment.

References: [1] Anesth Analg 71: 354-361, 1990; [2] Anesthesiology 73: A498, 1990. [3] Br J Anaesth 61: 738-742, 1988.