

## Conclusion

*While peak-to-peak analysis of inspired anesthetic agents is valid during periods when FGF significantly exceeds the patient's minute ventilation, its ability to reflect the actual concentration presented to the lungs is degraded significantly whenever FGF is less than minute ventilation.*

*Mean agent analysis remains accurate irrespective of the minute ventilation or the FGF.*

*With newer inhalation anesthetics and their advanced clinical features, precise agent analysis is necessary. When using low fresh gas flow, a mean agent analyzer is superior to a peak-to-peak analyzer.*

## Additional reading:

1. Bratzke E, Downs J, Smith R. Intermittent CPAP. A New Mode of Ventilation during General Anesthesia. *Anesthesiology* 1998;89:334-340
2. Dambrosio M, Roupie E, Mollet J, Anglade M, Vasile N, Lemaire F, Brochard L. Effects of Positive End-expiratory Pressure and Different Tidal Volume on Alveolar Recruitment and Hyperinflation. *Anesthesiology* 1997;87:495-503
3. Mecklenburgh, J, Mapleson W. Ventilatory assistance and respiratory muscle activity. Interaction in healthy volunteers. *Br. J. Anaesth.* 1998; 80:422-433
4. Rathegeber J. Grundlagen der maschinellen Beatmung: Handbuch für Ärzte und Pflegepersonal. Aktiv Druck & Verlag. Göttingen 1999



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# Clinical Focus

by *Datex-Ohmeda*

## Mean Inspired versus Peak-to-Peak Inspired Agent Analysis

**What does 6% vol / vol actually mean?**

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From the Monitoring Series

## Mean Inspired versus Peak-to-Peak Inspired Agent Analysis

Most clinicians believe that when the anesthetic agent analyzer displays an inspired anesthetic concentration of 6%, that it means 6% of all the tidal volume is composed of inhalation anesthetic. In many cases, this is not correct. This [Clinical Focus](#) is produced by the Department of Clinical Affairs at Datex-Ohmeda and will discuss mean and peak-to-peak inspired agent analysis.

Anesthetic agent analysis and monitoring inspired and end-expired agent concentration has become common. In agent monitors introduced in the 1980s, separate electronics measured inspired and expired agent concentrations. With the release of infrared agent monitors, continuous analysis of both inspired and expired gases was possible. Electronics and computer analysis during these early days of agent analyzers was limited to a method known as Peak-to-Peak analysis; breathing circuit gases were sampled and the amount of agent present was evaluated as it would rise and fall. Since these monitors could not detect ventilation only agent concentration, some assumptions were imposed on this analysis. Among these assumptions was that the highest value represented gases present in the inspiratory phase of ventilation. The other assumption was that the lower, or trough, value represented the exhalation phase. As a result they were displayed sometimes incorrectly as the inspired ( $F_{I\text{agent}}$ ) and expired ( $F_{E\text{agent}}$ ) values. As technology advanced agent monitors appeared that combined analysis of  $\text{CO}_2$  with anesthetic agent concentrations resulting in the ability to identify actual ventilation phases, overcoming the previous bias regarding the higher and lower peak agent concentrations representing inspired and expired phases. This advance allowed for changes during induction, maintenance and emergence.

There was another assumption that placed an unknown demand on the practice of anesthesia. That assumption was that the gas that passed by the sampling tube during inspiration had the same agent concentration throughout inspiration. This assumption requires that the entire tidal ventilation is comprised of fresh gas or a consistent mixture of fresh gas and rebreathed exhaled gas. In the presence of rebreathing this requirement is not met and rebreathing results in non-uniform mixtures in the inspiratory limb of the breathing circuit; the anesthetic agent concentration varies during inspiration relative to the amount of rebreathing present at any particular instant. This effect, the Dilution Effect of Rebreathing, is discussed in another [Clinical Focus](#), and has a direct impact on the ability of peak-to-peak analyzers to correctly identify the amount of agent the patient receives.

As an example, if the vaporizer is set to deliver 2% isoflurane and the fresh gas flow is 2 L/minute, anytime the patient's minute volume exceeds 2 L/minute, rebreathing of exhaled gases must occur. In peak-to-peak analysis, the agent concentration in the sampled gas will rise as the segment of inspiration containing fresh gas with its 2% isoflurane passes the sampling port. However, since only the initial gases within the sampling contain 2% isoflurane and the remainder contain some concentration less than 2%, the value displayed is erroneously high. Peak-to-peak agent analyzers do not take this variation in inspiratory concentration into consideration and, in this example, continue to display an inspired concentration of isoflurane as 2%. To accurately represent the effective inspired concentration reaching the patient, the measured value must reflect the mean value of all the gas reaching the patient during inspiration.

The intrinsic error in peak-to-peak analyzers is addressed by using a mean agent analyzer. Mean agent analyzers evaluate gases during the entire inspiratory phase, averaging the anesthetic agent concentration during its entire duration. A mean agent value will differ from peak-to-peak analysis as FGF is changed and as tidal volumes change because both of these alter the amount

of rebreathing and the resulting concentration variations during inspiration. To be absolutely accurate, the instantaneous inspired concentration and inspired flow should be multiplied and the product should be integrated or added and the result divided by the total flow. This is beyond the capability of present hardware and software, mostly due to the timing delay between flow at the airway and gas analyzed at the monitor end of the gas sample line. The time average of inspired concentration reported will closely approximate the "flow-weighted average" which is the effective concentration received by the lungs.

### Which value is correct?

$F_{I\text{agent}}$  value of a peak-to-peak analyzer is correct only if inspired concentration is constant throughout the inspiratory phase. This usually only occurs when the FGF greatly exceeds the minute volume. This is the result of the analyzer being presented only with FGF, uncontaminated by expired gas; no rebreathing occurs.

During anesthetic techniques where inspired flow far exceeds fresh gas flow, such as vital capacity induction using a breathing circuit primed with an induction concentration of anesthetic, or anesthetics administered with very low fresh gas flow or completely closed circuit, measurement and control of mean inspired concentration is crucial to the clinical technique.

The  $F_{E\text{agent}}$  value of a mean agent analyzer always reflects the actual percentage of anesthetic agent present in the inspired gases. This is true irrespective of the FGF, tidal volume, or ventilator settings. It has already been altered by these effects, and the instantaneous measurement and continuous averaging during inspiration has computed the mean value.

For either the peak-to-peak or the mean agent analyzer, the  $F_{E\text{agent}}$  value remains identical and correct. Exhaled gases have had the opportunity to equilibrate in the lungs and, as such, are relatively constant. The sample to be analyzed is taken at the end of expiration, just before the transition to inspiration.