Hypotensive Induced Changes in Dead Space/Tidal Volume Ratio and Arterial to End Tidal Carbon Dioxide Gradient

A Thesis Submitted for Partial Fulfillment of the M.D. Degree in Anesthesia

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Abstract

Background:

Adequacy of ventilation must be continually evaluated during anesthesia, and quantitative monitoring of carbon dioxide or volume of expired gas is strongly encouraged. ***But,*** it is not reliable to determine the adequacy of ventilation during deliberate hypotension because of the changes in the arterial to end tidal carbon dioxide gradient which occur in these conditions.

The aim of the present study was to assess the following during hypotensive anesthesia for middle ear surgery**:** 1.) The magnitude of changes in P (a-ET) CO_2 gradient. 2.) Changes in the lung compliance as well as in the ratio of physiological dead space to tidal volume (Vd_{phys}/V_T). 3.) To correlate between ($ETCO_2$) and mean arterial blood pressure (MAP) at steady state of ventilation. 4.) To evaluate whether or not the ventilatory requirements remain unaltered during this procedure.

Material and Methods:

100 patients aged 20-50 years, ASA I and II undergoing middle ear surgery under general anesthesia and controlled hypotension. A standard anesthetic technique was followed for all cases using, propofol, vecuronium, fentanyl and 100 % O2 supplemented with halothane. MAP was reduced to 60±5 mmHg in all patients using nitroglycerine infusion. The ETCO2, PaCO2, MAP, peak airway pressure plateau pressure and expiratory minute volume were recorded at two times: **Time 1 (T1)** measurements were taken after a steady state of ETCO2 of 35-40 mmHg for 10 min and before induction of hypotension. **Time (T2)** measurements were taken after steady state of MAP of 60±5 mmHg for 10 min.

Abstract

Results:

(1) There is no evidence of correlation between MAP and either $ETCO_2$, $P(a\text{-}ET)CO_2$ gradient or V_d/V_t ratio during anesthesia with normal MAP or with controlled hypotension. (2) $ETCO_2$ does not provide a stable reflection of $PaCO_2$. (3) There was no statistically significant change in lung compliance between time 1and time 2.

Conclusion:

During anesthesia, once normocapnia is achieved with normal arterial blood pressures, there is hardly any need to decrease ventilation after induction of controlled hypotension. That means that ETCO2 does not reflect changes in PaCO2 because as P (a-ET) CO2 gradient is increased, PaCO2 remains in the clinically acceptable range the larger decrease in ETCO2 during controlled hypotension is mainly due to the increase in the Vd phys/Vt and V/Q ratios.

Key words:

Arterial blood pressure. Controlled ventilation. End-tidal carbon dioxide. Hypotension. Middle ear surgery. Physiological dead space

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List of abbreviations

Abbreviation	Comment
ANP	Atrial natriuretic peptide
ADH	Anti diuretic hormone (vasopressin)
ASA	Anesthesia society association
BMI	Body mass index
CIC	Cardiac inhibitory center
CSL	Cardiac stimulatory center
CBF	Cerebral blood flow
COPD	Chronic obstructive pulmonary disease
Co_2	O_2 content
$C\bar{v}O_2$	Mixed venous oxygen content
COHb	Carboxyhemoglobin
CI	Confidence interval
ETCO2	End tidal carbon dioxide
ECG	Electrocardiogram
EEG	Electroencephalogram
ERV	Expiratory reserve volume
FiO_2	Fraction of inspired oxygen
Fe^{++}	Ferrous
FRC	Functional residual capacity
HPV	Hypoxic pulmonary vasoconstriction
HHb	Deoxygenated Hb
ICT	Intracranial tension

MAP	Mean arterial blood pressure
MAC	Minimum alveolar concentration
MetHb	Methemoglobin
NAD	Narkomed Anesthesia System
O_2Hb	Oxyhemoglobin
PaCO2	Arterial carbon dioxide tension
P(a-ET)CO2	Arterial to end tidal carbon dioxide gradient
PaO_2	Arterial oxygen tension
PGE_2	Prostaglandin E_2
Ppa	Pulmonary artery pressure
PA	Alveolar pressure
Ppv	Pulmonary venous pressure
PISF	Interstitial fluid pressure
Ppl	Intra pleural pressure
PAO_2	Alveolar oxygen pressure
PVR	Pulmonary vascular resistance
$P\bar{v}O_2$	Mixed venous oxygen tension
P_{50}	Hb is 50 percent saturated
PEEP	Positive end expiratory pressure
$PECO_2$	Mixed expired PCO_2
$PETO_2$	End-tidal PO_2
Qs/Qt	Pulmonary shunt fraction
QT	Cardiac output
R	Respiratory quotient
r	Pearson moment corelation

SVR	Systemic vascular resistance
SO_2	Oxygen saturation
Sao_2	Arterial oxygen saturation
SD	Standard deviation
TLC	Total lung capacity
TOF	Train of four
Vd_{phys}	Physiological dead space
Vt	Tidal volume
V/Q ratio	Ventilation to perfusion ratio
VMC	Vasomotor center
VE	Minute ventilation
Vd_{ALV}	Alveolar dead space
α	Solubility coefficient

Introduction and Aim of the work

Ensuring safety in anesthesia is the anesthetist main task, especially during certain types of operations that require special techniques to facilitate the surgical procedures.

For example, middle ear surgeries are microsurgeries that require the use of deliberate hypotension; which is a deliberate reduction of the arterial blood pressure by at least 20% of the baseline of the mean arterial blood pressure. It is used to facilitate the exposure of the surgical field.[1]

During deliberate hypotension, conventional monitoring of the patient may be unreliable and requires special awareness of the anesthetist to the expected physiological changes that accompany this technique.

Adequacy of ventilation must be continually evaluated, and quantitative monitoring of carbon dioxide or volume of expired gas is strongly encouraged.[2]

End tidal carbon dioxide (ETCO2) is an indispensable monitor for ensuring safety in modern anesthetic practice. *Capnography* is used clinically as an estimation of *arterial carbon dioxide tension (PaCO2).*[3,4]

Normally the arterial to end tidal carbon dioxide difference (Pa-ET CO2) gradient is less than 5 mmHg (approximately 3.6-4.6 mmHg) in healthy awake patients.[4]

However, it is not reliable for determining the adequacy of ventilation during low cardiac output because of the changes in the arterial to end tidal carbon dioxide gradient which occur in these conditions.[4]

The end tidal carbon dioxide tension is decreased to a greater extent than the arterial carbon dioxide tension. That leads to increase in the gradient between them.[4]

The changes are due to alterations in the ratio of physiological dead space to tidal volume (Vd phys/ Vt) and that of ventilation to perfusion V/Q ratio.[4]

These changes in the gradient between the arterial to end tidal carbon dioxide may lead to erroneous resetting of the ventilator parameters to maintain the normal value of the end tidal carbon dioxide tension and this resetting leads to increase in the value of the arterial carbon dioxide tension.

Therefore, end tidal carbon dioxide tension must be corelated to the arterial carbon dioxide tension to avoid hypercarbia that may lead to harmful effects on the patient e.g. (delayed recovery, increased intracranial tension and hypertension and tachycardia that lead to increased bleeding during surgery).[5] And those effects are unwanted during microsurgery.

Hypothesis:

There are many of studies investigated the P(a-ET)CO2 gradient in different situations e.g. effect of patient position during anesthesia [6], during caesarean section [7], and during craniotomy [8]. In this study we studied the ventilatory requirements during controlled hypotensive anesthesia and the relationship between changes in the perfusion and P(a-ET)CO2 gradient at steady state of ventilation.

Aim of the Work:

The aim of the present study is to assess the following during controlled hypotensive anesthesia for middle ear surgery:

1. The magnitude of changes in P (a-ET) CO_2 gradient.

2. Changes in the lung compliance as well as in the ratio of physiological dead space to tidal volume (Vd_{phys}/V_T).

3. To correlate between ($ETCO_2$) and mean arterial blood pressure (MAP) at steady state of ventilation.

DELIBERATE HYPOTENSION

Definition of deliberate hypotension:

It is a deliberate reduction of the arterial blood pressure by at least 20% of the baseline of the mean arterial blood pressure.[9]

Indications for deliberate hypotension:

Deliberate hypotension has many benefits in the following condition:

1. To facilitate the surgical technique: control of bleeding will improve the operative condition in some types of operation[1]:
    a. Microsurgery: middle ear, and endoscopic sinus surgery.
    b. Major cancer surgery: where bloodless operative filed facilitates delineation of malignant from non-malignant tissue and decreases blood losses.
    c. In head and neck surgery: to help identification of vital structures.
2. To reduce the need for blood transfusion: either to lower the risk of its complication, or because of patient objection (e.g. Jehovas witnesses).[10]
3. To lessen the risk of vessel rupture by decreasing intravascular tension in vascular aneurysm.[11]
4. In certain plastic operation: to decrease the oozing beneath skin flaps with improvement in wound healing and improved cosmetic results.