Drug Choices and Outcomes in Neuroanesthesia

or "Don't Touch That Vaporizer!"

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Objectives

- Be aware of the multiple goals to be met when providing anesthesia for patients with intracranial pathology
- Understand the effects of volatile and intravenous anesthetic agents on intracranial dynamics
- Be able to outline a rational choice of anesthetic when caring for patients with various intracranial situations

Overview

- Goals of anesthesia
- Effects of volatile anesthetics
- Effects of intravenous anesthetics
- Comparison of volatile anesthetics
- Comparison of intravenous anesthetics
- Volatile vs. intravenous anesthetics
- What's best?

Goals of Anesthetic Management

- Hemodynamic stability
- Maintenance of cerebral perfusion pressure
- Control of intracranial pressure
- Optimal surgical conditions (slack brain)
- Smooth emergence
- Rapid awakening for early neurologic assessment

Ideal Anesthetic Agent

- Maintain CBF without affecting autoregulation
- Minimize detrimental changes in Intracranial Pressure (ICP)
- Preserve reactivity of cerebral arterioles to P_aCO_2 changes
- Decrease $CMRO_2$ with cerebral protection effects
- Devoid of seizure activity
- Preserve hemodynamic stability, especially Cerebral Perfusion Pressure (CPP)
- Devoid of arrhythmogenic effect

Normal Values

Table 21–1 Normal cerebral physiologic values

CBF	
Global	45-55 mL/100 g/min
Cortical (mostly gray matter)	75-80 mL/100 g/min
Subcortical (mostly white matter)	~20 mL/100 g/min
$CMRO_2$	3-3.5 mL/100 g/min
CVR	1.5-2.1 mm Hg/100 g/min/mL
Cerebral venous Po_2	32-44 mm Hg
Cerebral venous So_2	55%-70%
ICP (supine)	8-12 mm Hg

CBF, cerebral blood flow; $CMRO_2$, cerebral metabolic rate of oxygen; CVR, cerebral vascular resistance; ICP, intracranial pressure.

- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed; p. 814

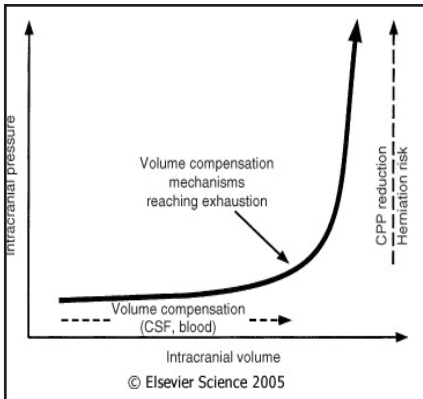
Determinants of ICP

(and What We Can Control)

- Brain tissue
- Intra- and extracellular fluid (edema)
- CSF
- Blood (arterial/venous)
- Airway or intrathoracic pressure
- Jugular venous pressure
- P_aCO_2
- P_aO_2
- Anesthetics
- Vasodilators
- Seizures
- Temperature
- Arousal
- Pain

Why Does ICP Matter?

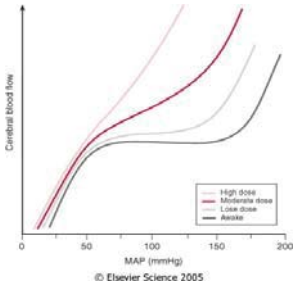
- Sustained ICP > 20 mm Hg is abnormal
- ICP 20 – 40 mm Hg is considered moderate intracranial hypertension
- ICP > 40 mm Hg is life-threatening
- Increased ICP results in secondary injury due to ischemia from reduced CPP and distortion of intracranial structures such as the brainstem



- Drummond JC and Patel PM in Miller's Anesthesia, 6th Ed; p. 2128

Effects of Volatile Agents

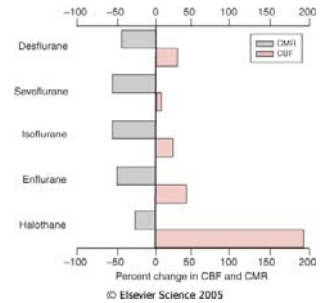
(Are they all created equal?)



- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed; p. 817

Effects of Volatile Agents

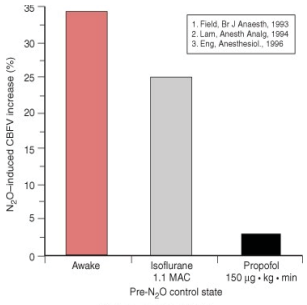
(Are they all created equal?)



- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed; p.826

Effects of Volatile Agents

(Are they all created equal?)



- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed; p. 830

Effects of Volatile Agents
(Are They All Created Equal?)

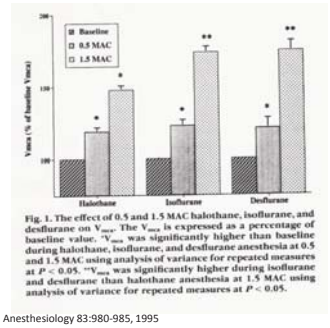


Fig. 1. The effect of 0.5 and 1.5 MAC halothane, isoflurane, and desflurane on V_{mca}. The V_{mca} is expressed as a percentage of baseline value. *V_{mca} was significantly higher than baseline during halothane, isoflurane, and desflurane anesthesia at 0.5 and 1.5 MAC using analysis of variance for repeated measures at $P < 0.05$. **V_{mca} was significantly higher during isoflurane and desflurane than halothane anesthesia at 1.5 MAC using analysis of variance for repeated measures at $P < 0.05$.

- Matta BF et. al., Anesthesiology 83:980-985, 1995

Effects of Volatile Agents
(Are they all created equal?)

- Isoflurane has been the "gold standard" of volatile agents for some time, but –
- At both 0.5 and 1.5 MAC Sevoflurane increases V_{mca} less (4 and 17%) than Isoflurane (19 and 72%)
  Matta BF et. al., Anesthesiology 1999; 91:677-80
- Sevoflurane preserves autoregulation better than Isoflurane
  Summors AC et. al. Anesth Analg 1999; 88:341-5
- At 0.4 MAC in normal volunteers, Sevoflurane produced less increase in CBV than Isoflurane
  Lorenz IH et. al., J Neurosurg Anesthesiol 2001; Vol 13 (4):288-295
- At both 1.0 and 1.5 MAC Sevoflurane increased V_{mca} less (max 7%) than Desflurane (max 65%)
  Bedforth NM et. al., Anesth Analg 2000; 91:152-5

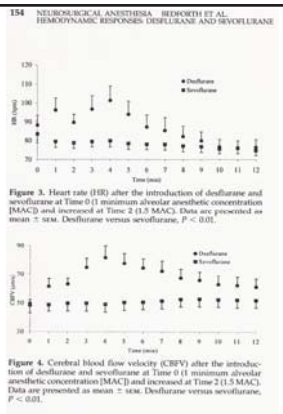


Figure 3. Heart rate (HR) after the introduction of desflurane and sevoflurane at Time 0 (1 minimum alveolar anesthetic concentration [MAC]) and increased at Time 2 (1.5 MAC). Data are presented as mean ± SEM. Desflurane versus sevoflurane, $P < 0.01$.

Figure 4. Cerebral blood flow velocity (CBFV) after the introduction of desflurane and sevoflurane at Time 0 (1 minimum alveolar anesthetic concentration [MAC]) and increased at Time 2 (1.5 MAC). Data are presented as mean ± SEM. Desflurane versus sevoflurane, $P < 0.01$.

- Bedforth NM et. al.

But What Happens During Brain Surgery?

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)

- In a study of patients with supratentorial mass lesions and mass effect on CT, in the presence of hyperventilation (P_aCO_2=25 mm Hg), 1 MAC Desflurane in air:O_2 increased Cerebrospinal Fluid Pressure greater than Isoflurane (18 vs. 8 mm Hg)

  Muzzi DA et. al., Anesthesiology 1992; 76:720-724

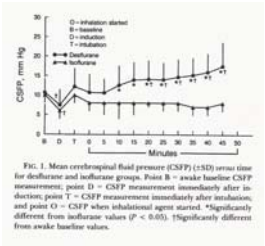


FIG. 1. Mean cerebrospinal fluid pressure (CSFP) (±SD) versus time for desflurane and isoflurane groups. Point B = awake baseline CSFP measurement; point D = CSFP measurement immediately after induction; point T = CSFP measurement immediately after intubation; and point O = CSFP when inhalational agent started. *Significantly different from isoflurane values ($P < 0.05$). †Significantly different from awake baseline values.

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)

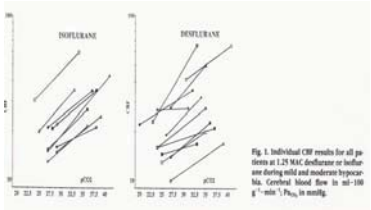


Fig. 1. Individual CBF results for all patients at 1.25 MAC desflurane or isoflurane during mild and moderate hypocarbia. Cerebral blood flow in ml·100 g^{-1}·min^{-1}; $P_{ET}CO_2$ in mmHg.

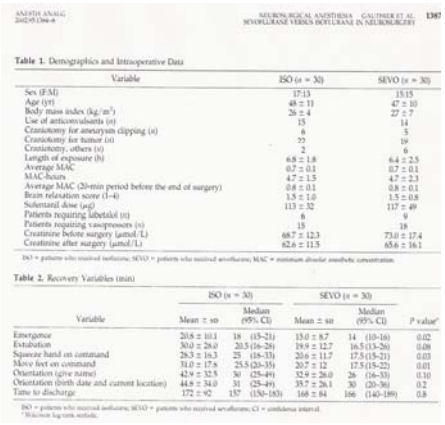
- In a study of patients with intracranial mass lesions (with and without evidence of increased ICP, $P_{et}CO_2$=21 mm Hg), CBF was slightly higher at 1.0 MAC Isoflurane than Desflurane, but there were no differences at 1.25 and 1.5 MAC
- CBF under anesthesia was 17-35 ml/100g/min

Ornstein E et. al., Anesthesiology 1993; 79:498-502

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)

- In patients undergoing craniotomy with a background of Thiopental/Sufentanil and hyperventilation (P_aCO_2=30-35 mm Hg), Sevoflurane had earlier recovery profile than Isoflurane (moving feet: 24 minutes Sevo vs. 43 minutes Iso). Hemodynamic variables and brain relaxation scores were similar

Gauthier A et. al., Anesth Analg 2002; 95:1384-8



ANESTH ANALG 2002;95:1384–8 NEUROSURGICAL ANESTHESIA GAUTHIER ET AL. 1387
SEVOFLURANE VERSUS ISOFLURANE IN NEUROSURGERY

Table 1. Demographics and Intraoperative Data

Variable	ISO (n = 30)	SEVO (n = 30)
Sex (F:M)	17:13	15:15
Age (yr)	48 ± 11	47 ± 10
Body mass index (kg/m²)	26 ± 4	27 ± 7
Use of anticonvulsants (n)	15	14
Craniotomy for aneurysm clipping (n)	6	5
Craniotomy for tumor (n)	22	19
Craniotomy, others (n)	2	6
Length of exposure (h)	6.8 ± 1.8	6.4 ± 2.5
Average MAC	0.7 ± 0.1	0.7 ± 0.1
MAC-hours	4.7 ± 1.5	4.7 ± 2.3
Average MAC (20-min period before the end of surgery)	0.8 ± 0.1	0.8 ± 0.1
Brain relaxation score (1–4)	1.5 ± 1.0	1.5 ± 0.8
Sufentanil dose (μg)	113 ± 32	117 ± 49
Patients requiring labetalol (n)	6	9
Patients requiring vasopressors (n)	13	18
Creatinine before surgery (μmol/L)	68.7 ± 12.3	73.0 ± 17.4
Creatinine after surgery (μmol/L)	62.6 ± 11.5	65.6 ± 16.1

ISO = patients who received isoflurane; SEVO = patients who received sevoflurane; MAC = minimum alveolar anesthetic concentration.

Table 2. Recovery Variables (min)

Variable	ISO (n = 30) Mean ± SD	ISO (n = 30) Median (95% CI)	SEVO (n = 30) Mean ± SD	SEVO (n = 30) Median (95% CI)	P value*
Emergence	20.8 ± 10.1	18 (15–21)	13.0 ± 8.7	14 (10–16)	0.02
Extubation	30.0 ± 26.0	20.5 (16–28)	19.9 ± 12.7	16.5 (13–26)	0.08
Squeeze hand on command	26.3 ± 16.3	25 (16–33)	20.6 ± 11.7	17.5 (15–21)	0.03
Move feet on command	31.0 ± 17.8	25.5 (20–35)	20.7 ± 12	17.5 (15–22)	0.01
Orientation (give name)	42.9 ± 32.5	30 (25–49)	32.9 ± 26.0	26 (16–33)	0.10
Orientation (birth date and current location)	44.8 ± 34.0	31 (25–49)	35.7 ± 26.1	30 (20–36)	0.2
Time to discharge	172 ± 92	157 (150–183)	166 ± 84	166 (140–189)	0.8

ISO = patients who received isoflurane; SEVO = patients who received sevoflurane; CI = confidence interval.
* Wilcoxon log-rank statistic.

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)

- In a study of children (mean age 20 months) with suspected ICP above normal given a background of Fentanyl/ N_2O 60% and normocarbia, 0.5-1.0 MAC Isoflurane, Sevoflurane, and Desflurane similarly increased ICP and decreased MAP and CPP in a dose-dependent manner. ICP increased more (n.s.) with higher baseline values with Desflurane

Sponheim S et. al., Acta Anaesthesiol Scand 2003; 47:932-8

- In a study comparing 0.5, 1.0, or 1.5 MAC Isoflurane or Sevoflurane in air with Sufentanil ($P_{et}CO_2$=35-40 mm Hg) there was no change in ICP and a decrease in CBF with both agents; CPP decreased at 0.5 MAC with Sevoflurane and all levels of Isoflurane; MAP and CPP were lower with Isoflurane compared to Sevoflurane.

Artru AA et. al., Anesth Analg 1997; 85:587-92

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)

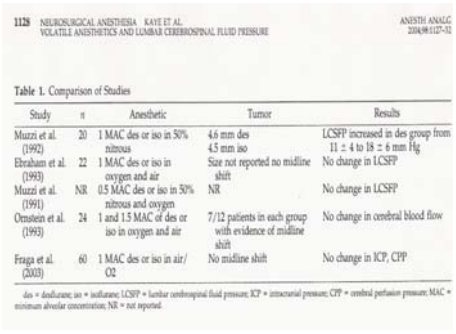
- In patients with supratentorial tumors and no evidence of midline shift receiving 60% N_2O/Fentanyl ($P_{et}CO_2$=35 mm Hg), both Isoflurane or Desflurane 1.0 MAC caused no change in ICP, a 19% decrease in MAP, and a 22% decrease in CPP.

Fraga M et. al., Anesthesiology 2003; 98:1085-90

- In patients with supratentorial lesions with mass effect, there was no change from baseline or difference between 1.2 MAC Isoflurane or Desflurane with hypocapnia (P_aCO_2=30 mm Hg) in CSFP or MAP; There was no difference between agents in CPP (Desflurane CPP tended to be lower than baseline as duration increased). Time to respond to commands was 50% shorter with Desflurane (30 vs. 72 minutes, n.s.)

Kaye A et. al., Anesth Analg 2004; 98: 1127-32

Effects of Volatile Agents
(Comparative Studies, Intracranial Surgery)



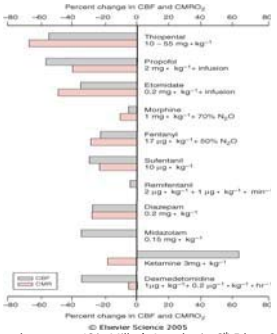
1128 NEUROSURGICAL ANESTHESIA KAYE ET AL. ANESTH ANALG
VOLATILE ANESTHETICS AND LUMBAR CEREBROSPINAL FLUID PRESSURE 2004;98:1127–32

Table 1. Comparison of Studies

Study	n	Anesthetic	Tumor	Results
Muzzi et al. (1992)	20	1 MAC des or iso in 50% nitrous	4.6 mm des 4.5 mm iso	LCSFP increased in des group from 11 ± 4 to 18 ± 6 mm Hg
Ebrahim et al. (1993)	22	1 MAC des or iso in oxygen and air	Size not reported no midline shift	No change in LCSFP
Muzzi et al. (1991)	NR	0.5 MAC des or iso in 50% nitrous and oxygen	NR	No change in LCSFP
Ornstein et al. (1993)	24	1 and 1.5 MAC of des or iso in oxygen and air	7/12 patients in each group with evidence of midline shift	No change in cerebral blood flow
Fraga et al. (2003)	60	1 MAC des or iso in air/O2	No midline shift	No change in ICP, CPP

des = desflurane; iso = isoflurane; LCSFP = lumbar cerebrospinal fluid pressure; ICP = intracranial pressure; CPP = cerebral perfusion pressure; MAC = minimum alveolar concentration; NR = not reported.

Effects of Intravenous Agents



- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed., p. 821

But What Happens During Brain Surgery?

Effects of Intravenous Agents
(Comparative Studies, Intracranial Surgery)

- In patients with tumors and a background of 60% N_2O and normocarbia (P_aCO_2=36 mm Hg) Sufentanil (89%) and Alfentanil (22%) increased CSFP compared to Fentanyl, and all decreased CPP (Fentanyl=14%; Sufentanil 25%; Alfentanil 37%)

  Marx W et. al., J Neurosurg Anesthesiol 1989; Vol 1(1):3-7
- In patients with tumors receiving 60-70% N_2O with $P_{et}CO_2$=25 mm Hg and either Alfentanil, Fentanyl, or Sufentanil, although the Alfentanil group received ephedrine more frequently, there was no difference in recovery profiles or intraoperative brain conditions

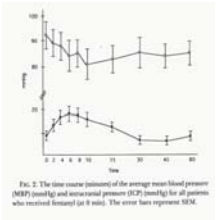
  From RP et. al., Anesthesiology 1990; 73:896-904

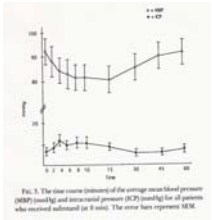
Effects of Intravenous Agents
(Comparative Studies, Intracranial Surgery)

- In sedated patients with head trauma (GCS= 6-7)and P_aCO_2=30-35 mm Hg, Propofol (2mg/kg bolus with 150mcg/kg/min infusion) decreased ICP (11.3-9.2 mm Hg), decreased MAP (25%), decreased CBF (35-26 ml/100g/min), and decreased CPP (82-59 mm Hg)

  Pinaud M et. al., Anesthesiology 1990; 73:404-9

Effects of Intravenous Agents
(Comparative Studies, Intracranial Surgery)





- In patients with head trauma (GCS=6) and hypocapnia (P_aCO_2=27 mm Hg), boluses of Fentanyl (3mcg/kg) or Sufentanil (0.6mcg/kg) increased ICP (F=8 mm Hg, S=6 mm Hg) and decreased MAP (F=11 mmHg, S=10 mm Hg)

  Sperry RJ et al, Anesthesiology 1992; 77:416-420

Effects of Intravenous Agents
(Comparative Studies, Intracranial Surgery)

- In patients with tumors and a background of Isoflurane 0.3-0.8% in 66% N_2O and P_aCO_2<30 mm Hg, boluses of Remifentanil (0.5 mcg/kg and 1.0 mcg/kg) or Alfentanil (10 mcg/kg and 20 mcg/kg), neither caused a change in ICP. Effects on MAP were similar (decreased)

  Warner DS et.al., Anesth Analg 1996; 83:348-53
- In patients with tumors given Isoflurane (low dose, unspecified)/66% N_2O and P_aCO_2=28 mm Hg, Remifentanil and Fentanyl did not differ in ICP, CPP, MAP (except for intubation), brain condition, or recovery variables.

  Guy J et. al., Anesthesiology 1997; 86:514-24

Effects of Intravenous Agents
(Comparative Studies, Intracranial Surgery)

- In patients with tumors receiving Propofol or Isoflurane with or without N_2O, the use of Fentanyl (customary manner) was associated with delayed emergence (at 10 minutes but not 20) and greater Isoflurane use compared with Remifentanil (d/c at dressing)

  Balakrishnan G et. al., Anesth Analg 2000: 91:163-9
- In patients for craniotomy with Propofol and P_aCO_2=30-35 mmHg, Remifentanil required less Propofol compared to Fentanyl and Alfentanil, and was associated with more rapid recovery than Alfentanil (but not Fentanyl). All agents decreased MAP post-induction

  Coles JP et. al., J Neurosurg Anesthesiol 2000; Vol 12 (1):15-20

How do the Volatile Agents Compare to Intravenous Agents?

Volatile vs. Intravenous
(Comparisons, Intracranial Surgery)

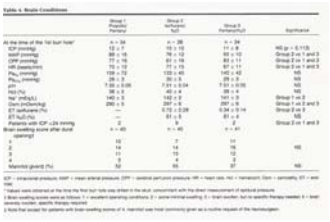
- Patients without signs of high ICP given either Isoflurane (0.5-1.5%) or Propofol infusion (N_2O 50% given to both after dural opening) found lower CPP (81 vs. 70 mm Hg) at induction, lower CSFP (15.2 vs. 11.6 mm Hg) and better recovery variables at 20-30 minutes with Propofol

Ravussin P et. al., J Neurosurg Anesthesiol 1991; Vol 3(2):85-95

Volatile vs. Intravenous
(Comparisons, Intracranial Surgery)

- In patients with tumors given either Propofol/Fentanyl, Isoflurane/N_2O, or Fentanyl/N_2O with P_aCO_2=30 mm Hg, there were no differences in mean ICP (ISO/N_2O was associated with a greater number of patients with ICP>24 mm Hg) or brain condition. MAP and CPP was lower with Iso/N_2O. Emergence was more rapid with Fentanyl/N_2O.

Todd MM et. al., Anesthesiology 1993; 78:1005-1020



Volatile vs. Intravenous
(Comparisons, Intracranial Surgery)

- In patients with pituitary tumors and no mass effect, after induction with Fentanyl/Propofol/N_2O and normocarbia, Desflurane and Isoflurane 0.5 and 1.0 MAC increased CSFP (5 and 4 mm Hg) and decreased CPP (12 and 15 mm HG) compared to Propofol infusion (no change)

Talke P et. al., Anesthesiology 1996; 85:999-1004

- In patients with pituitary tumors and no mass effect, similar conditions to above, Sevoflurane increased CSFP (2 mm Hg) and decreased CPP (11-15 mm Hg) at 0.5 and 1.0 MAC compared to Propofol infusion (no change)

Talke P et. al., Anesthesiology 1999; 91:127-30

- In patients with supratentorial tumors given N_2O, the use of either a Propofol infusion, Isoflurane, or Isoflurane switching to Propofol at dural closure was not associated with any differences in hemodynamic or recovery variables.

Talke P et. al., Anesth Analg 2002; 95:430-5

Volatile vs. Intravenous
(Comparisons, Intracranial Surgery)

- In patients with tumors maintained with Fentanyl, the use of a Propofol infusion was associated with a lower ICP (7 mmHg) and higher CPP (80 mm Hg) compared to Isoflurane (12/60 mm Hg) or Sevoflurane (11/63 mm Hg)

Petersen KD et. al., Acta Neurochir Suppl 2002; 81:89-91

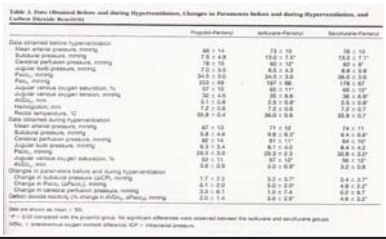
- In patients with mass lesions induced with Propofol/Fentanyl/air and P_aCO_2=35 mm Hg, there was no difference in brain condition or recovery variables between Sevoflurane/Fentanyl or Propofol/Remifentanil. There was more hypotension in the TIVA group.

Magni G et. al., J Neurosurg Anesthesiol 2005; Vol 17 (3):134-8

Volatile vs. Intravenous
(Comparisons, Intracranial Surgery)

- In patients with tumors and $P_{et}CO_2$=30-40 mm Hg, receiving either Propofol/Fentanyl, Isoflurane/Fentanyl, or Sevoflurane/Fentanyl, ICP was lower and MAP and CPP higher with TIVA. Dural tension was significantly lower with TIVA and Sevo. Cerebral swelling after dural opening was lower with TIVA. No difference in ICP, CPP, or CO_2 reactivity between volatiles.

Petersen KD et. al., Anesthesiology 2003; 98:329-36



CBF, ICP, CBV, or CPP?

- CPP = MAP – ICP
- Want to maintain CPP = 70 – 90 mm Hg
- ICP affected by intracranial volume
- Intracranial volume has 4 components:
  - Tissue volume
  - CSF volume
  - Fluid compartment (edema)
  - Blood volume (arterial and venous)
- CBF reflects arterial volume – how much does this really affect total CBV?

CBF, ICP, CBV, or CPP?

- Approximately 10% of CBV is in the arterioles and capillaries – the compartment which reacts to CO_2 and anesthetic agents

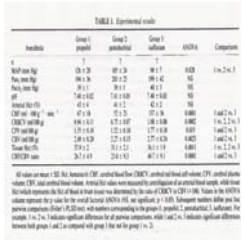
  Schmidek HH et. al., Neurosurgery 1985; 17:663-78

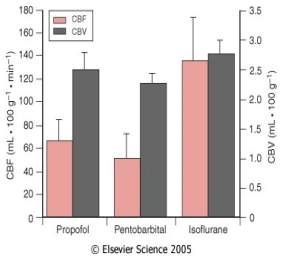
  Heistad DD et. al. in Handbook of Physiology; American Physiologic Society, 1983

- In dogs breathing 60-70% N_2O and exposed to Fentanyl, 1.4% Isoflurane, 0.8% Halothane, or 2.2% Enflurane for 3.5 hours:
  - *Halothane: ↑CBV (11%), ↑ICP (stable)*
  - *Enflurane: ↑CBV (9%), ↑ICP (continued to rise, even after Enf off)*
  - *Isoflurane ↑CBV (10%), ↑ICP (only for 20 min, then returned to baseline)*
  - *Fentanyl: ↓CBV (8%), ↓ICP (only for first 20 min, then returned to baseline)*

  Artru AA, Anesthesiology 1983; 58:533-9
  Artru AA, Anesthesiology 1984; 60:575-9

CBF, ICP, CBV, or CPP?





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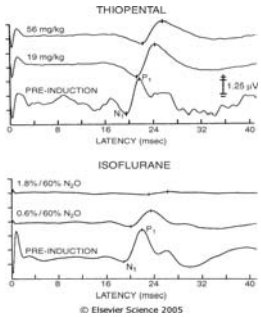
- In rats exposed to Propofol, Pentobarbital, or Isoflurane anesthesia, though CBF was 2.0-2.6 times greater with Iso than Prop or Pento, CBV was only 10-18% greater with Iso than with Prop or Pento

  Todd MM and Weeks J, J Neurosurg Anesthesiol 1996; Vol 8 (4):296-303

Volatile vs. Intravenous Agents
(Is There Really a Difference in Mechanism?)



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- Patel PM and Drummond JC in Miller's Anesthesia, 6th Ed., p. 815

Volatile vs. Intravenous Agents
(Is One Really Better?)

- It depends on how you define "better"
  - Quicker emergence (short term outcome)
  - Ease of titration/administration
  - Hemodynamic stability
  - Brain conditions
  - Long term outcomes (no data)
  - ¢ versus $ (*cost containment*)

One More Note

- In many of the studies comparing volatile agents, or volatile to intravenous agents, exclusion criteria included evidence of increased intracranial pressure such as mass shift, altered mental status, or abnormal measured ICP

My Opinion

- For all agents, the ultimate condition of the patient will be determined by the sum of the effects of the chosen agent on CBF, $CMRO_2$, vascular tone, MAP, CO, CSF formation/reabsorption, and CBV.
- The preponderance of evidence is that intravenous agents (Propofol, Barbiturates, Etomidate, Benzodiazepines, synthetic opiates (phenylpiperidine)) have less deleterious, and more salutary effects that are more predictable on intracranial dynamics than volatile agents, especially if MAP is maintained.
- Isoflurane, Sevoflurane, and Desflurane are similar, though the edge probably should go to Sevoflurane, and their ultimate effects on ICP/CPP are less predictable.
- There is no overwhelming evidence that one technique is superior to any other in terms of short term recovery profile, if the agents chosen are properly administered.
- Choose your poison (agents) wisely given the goals of anesthesia and surgery, and the condition of the patient such as……

My Opinion

- If the patient is wide awake, appearing for elective surgery, and is well-compensated in terms of intracranial dynamics:

  Either volatile or TIVA are appropriate taking care to avoid bad things like –

  Hypotension (remember CPP)
  Hypertension
  Hypoxemia
  Hypercarbia
  Inadequate anesthesia at critical points

  Remember – it's more important how you do it, than what you use.

My Opinion

- If the patient has signs or symptoms of high ICP (altered mental status, head injury, ventriculostomy/ICP monitor in place, midline shift on CT/MRI, etc.):

  -Management of the ICP/CBF/CBV/CPP is critical

  -TIVA is preferable, at least until the dura is opened and the effects of anesthetics on the brain bulk can be assessed directly

  -Keep a very close eye on CPP (>70 mm Hg)

  -Think/Think/Think: MAP-ICP

Comparative Costs

- 1993:
  - Propofol/Fentanyl = $152
  - Isoflurane/N_2O = $49
  - Fentanyl/N_2O = $15
- 2002:
  - Isoflurane/N_2O = $17
  - Propofol/Fentanyl/N_2O = $114
  - Isoflurane/N_2O then Propofol = $31

THE END