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# Navigator in everyday use

(& some observations on Aisys with  
ETc)

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Ross Kennedy  
Christchurch  
NEW ZEALAND



NIEUW-ZEELANDERSSTR.  
RUE DES NEO - ZELANDAIS



# The Analogue Exponential Infusion Device

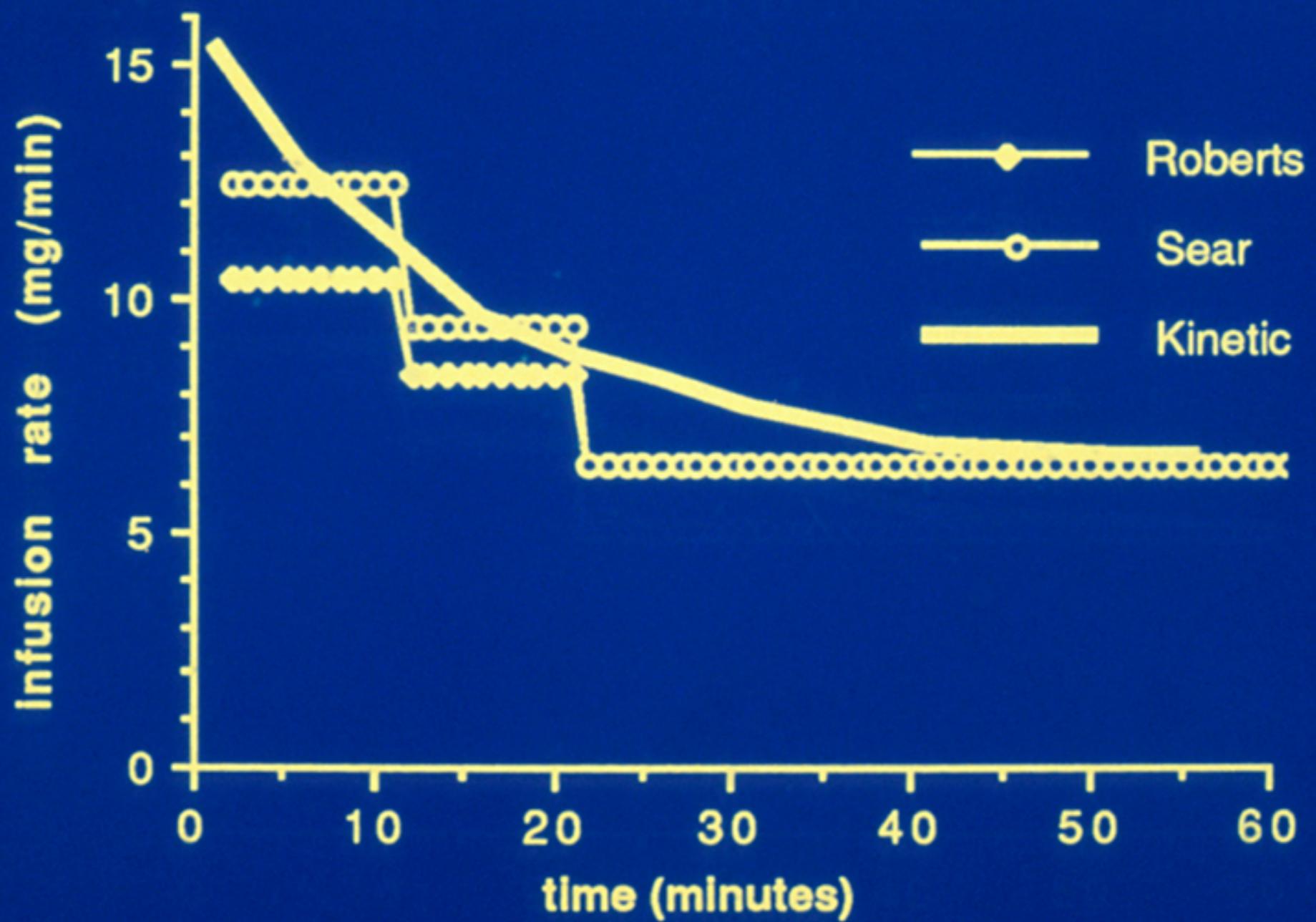


Bag of 5% dextrose with propofol 2mg/ml  
(500mg in 250ml)

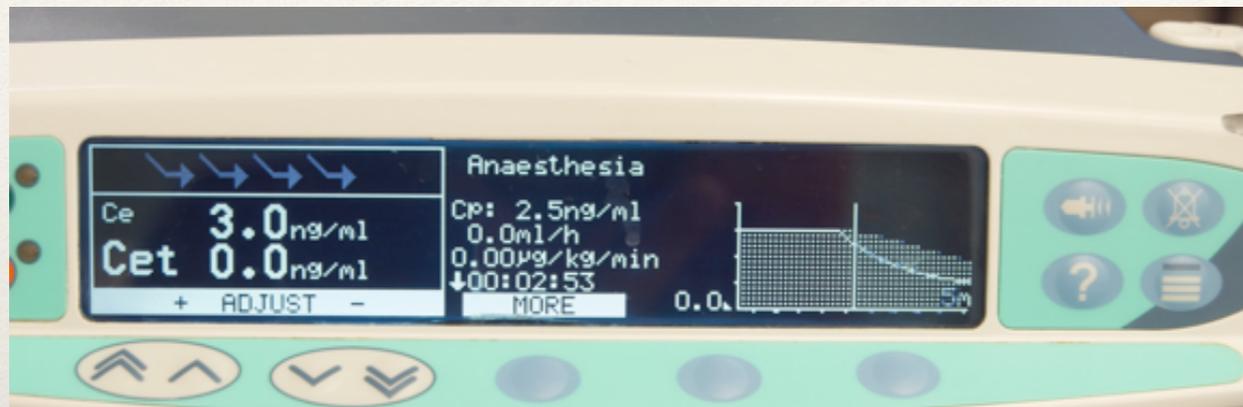
Burette containing 250 mg propofol  
made up to 45ml

RUN Run at 1 drop / second (= 3ml/min)

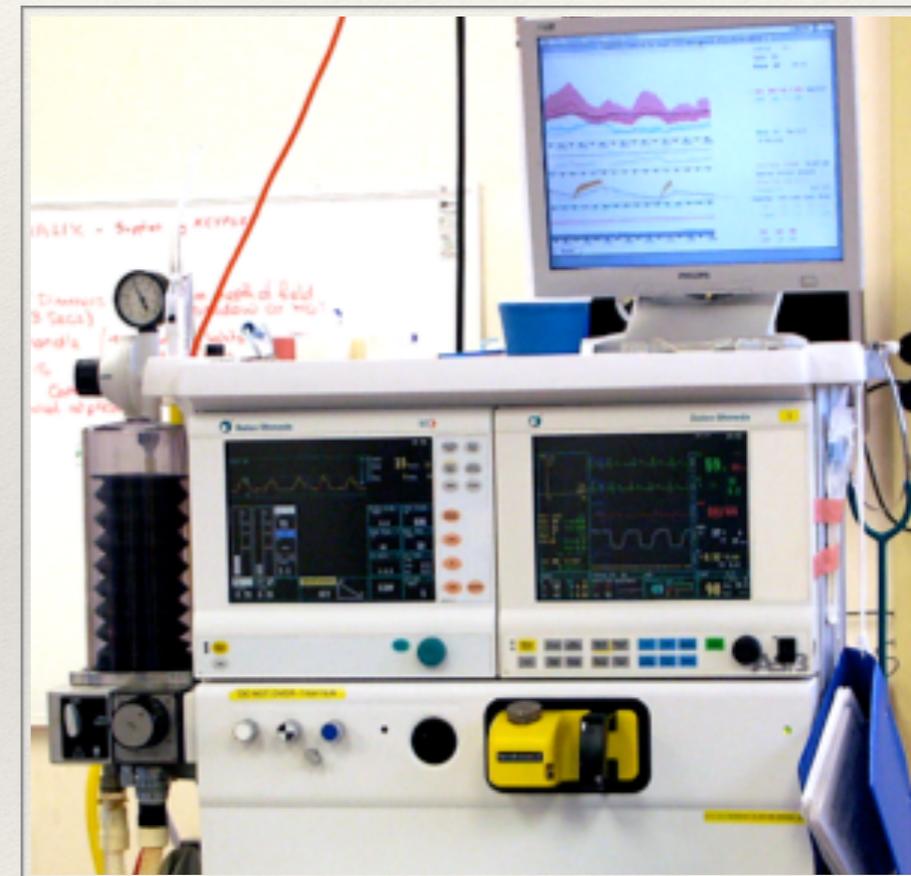
# Comparison of Propofol Infusion Regimes



# Why not think about volatile kinetics in the same way as infusions



- ❖ TCI pumps display effect site and forward prediction
- ❖ We can do the same with volatiles





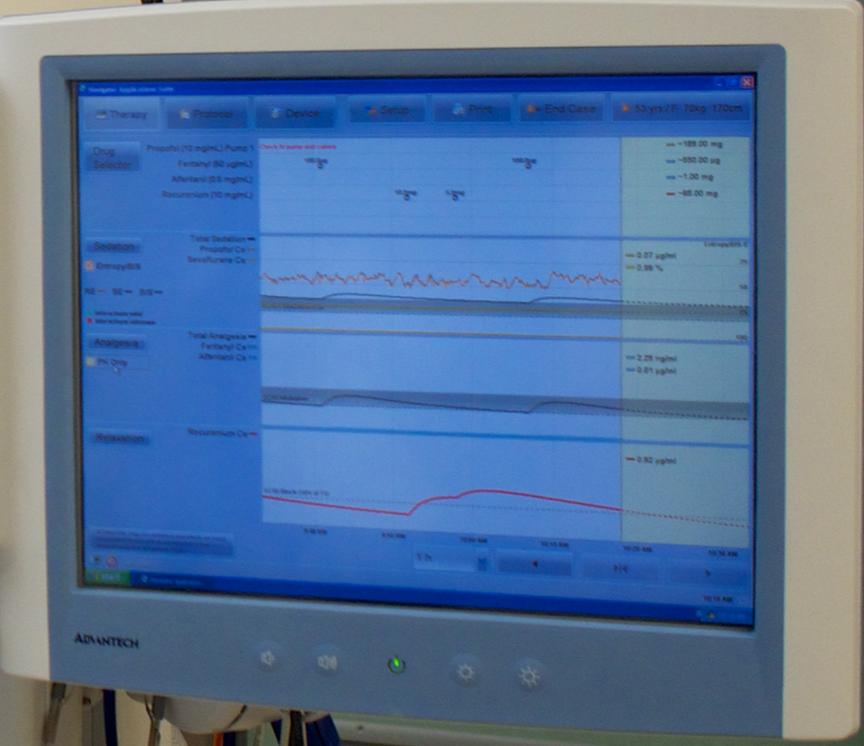
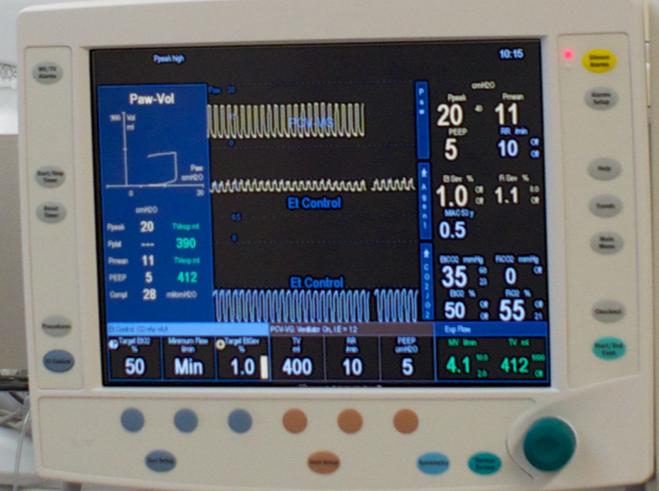
- ❖ Take FGF, vaporiser dial settings and ET-agent
- ❖ Predict future end-tidal and effect site
  - ❖ (Similar display on Drager Perseus)
- ❖ = Manual Target Control
- ❖ Worked on validating effect site approach





CH-CH  
OPERATING THEATRE SUITE

ANAES



David now wants  
Russions on his CABG  
Setup

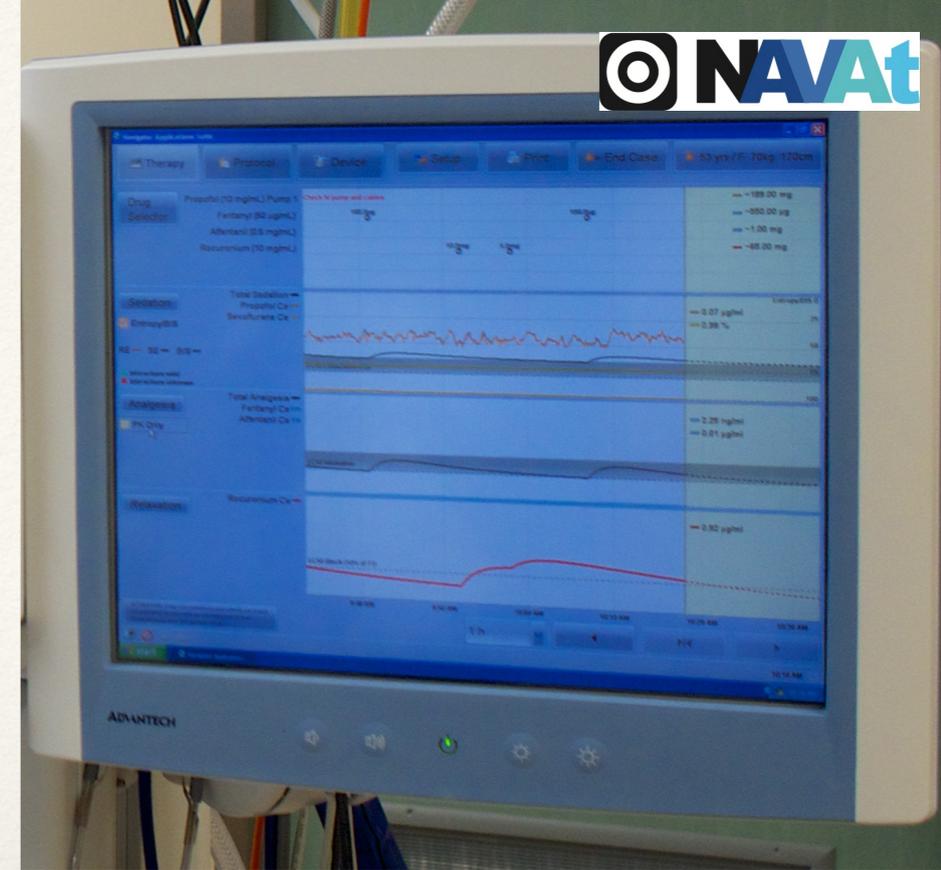
only have 1x2mm  
1x3mm



❖ What is Navigator?

❖ What use is it?

❖ What does it show us?

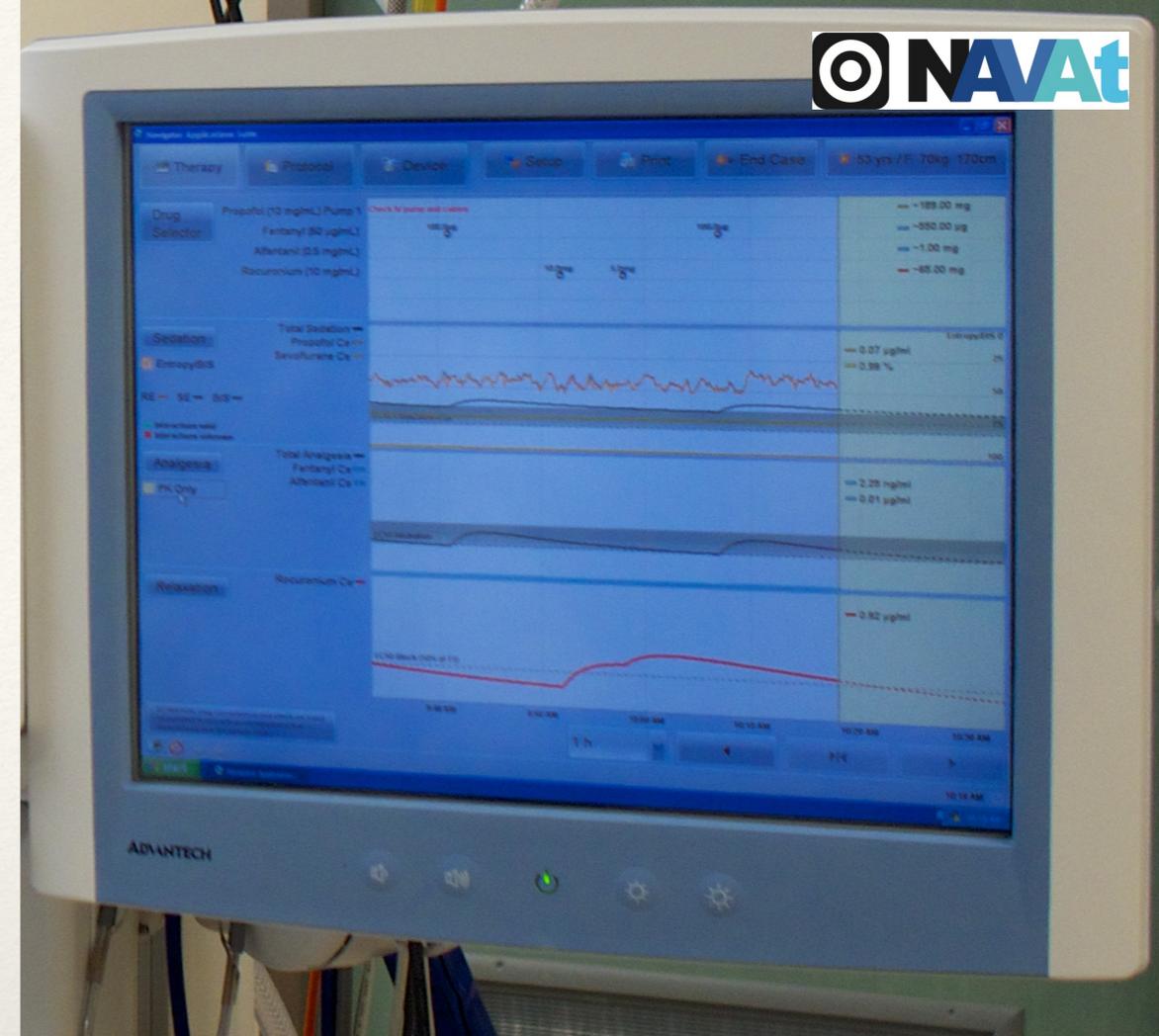


❖ Calculated effect site levels and predictions

❖ based on inputs

❖ Graphical display of interaction “probabilities”

- ❖ A bigger advance than TCI
- ❖ Anaesthesia kinetics (almost) never at equilibrium  
despite the way “everyone” is taught & thinks
- ❖ Illustrates principles & interactions non intuitive; can't do in your head
- ❖ Interaction display as a “monitor”
- ❖ Makes pharmacology as deterministic as physiology



Therapy

Protocol

Device

Setup

Print

End Case

40 yrs / M 80kg 170cm

Drug Selector

Fentanyl (50 µg/mL)  
Propofol (10 mg/mL)  
Rocuronium (10 mg/mL)

Sedation

Total Sedation —  
Propofol Ce —

 Entropy/BIS

▲ Interactions valid  
■ Interactions unknown

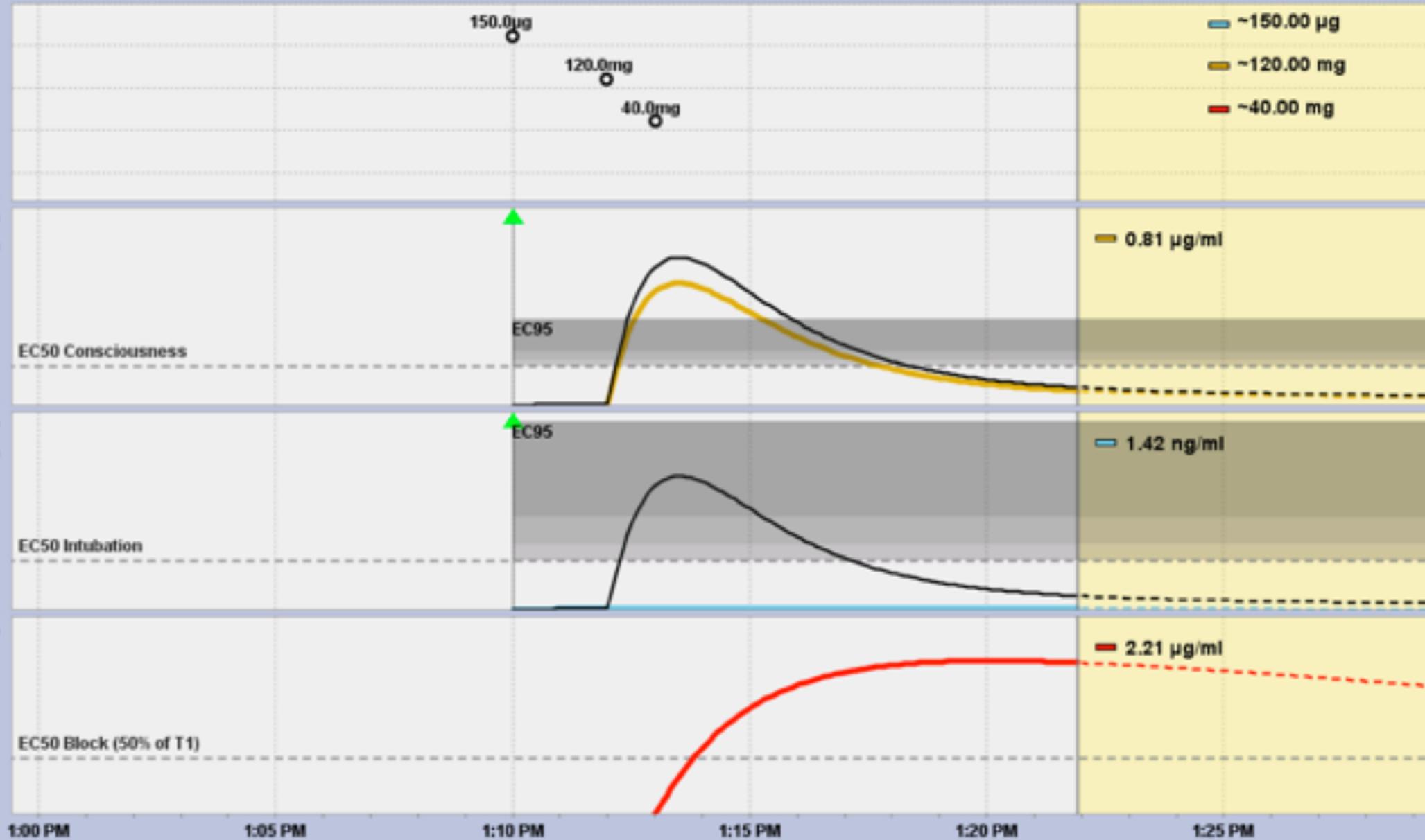
Analgesia

Total Analgesia —  
Fentanyl Ce —

 PK Only

Relaxation

Rocuronium Ce —



ATTENTION: Drug concentrations and effects are based on published models and do not represent actual measurements from this patient. More...

30 min

1:21 PM

Therapy

Protocol

Device

Setup

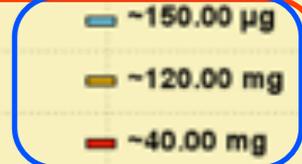
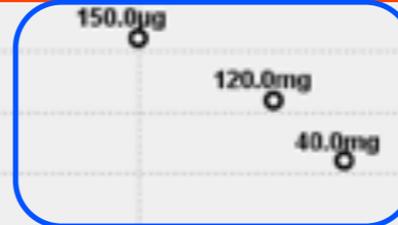
Print

End Case

40 yrs / M 80kg 170cm

Drug Selector

Fentanyl (50 µg/mL)  
Propofol (10 mg/mL)  
Rocuronium (10 mg/mL)



Sedation

Total Sedation  
Propofol Ce

Entropy/BIS

Interactions valid  
Interactions unknown

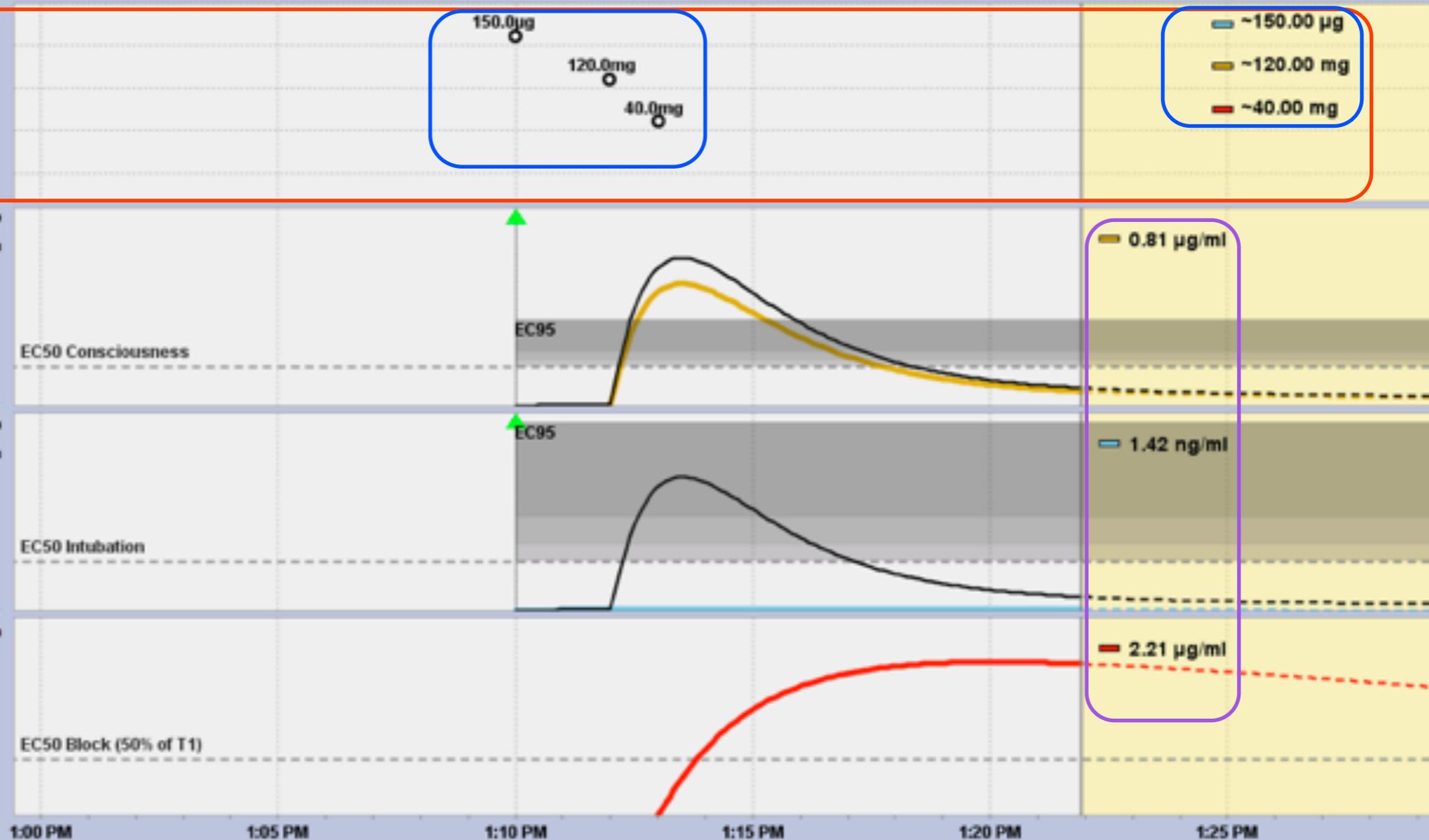
Analgesia

Total Analgesia  
Fentanyl Ce

PK Only

Relaxation

Rocuronium Ce



ATTENTION: Drug concentrations and effects are based on published models and do not represent actual measurements from this patient. More...

30 min

# Drugs modelled

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## ❖ Analgesics

- ❖ Remifentanil, Fentanyl, Sufentanil, Alfentanil (not morphine)

## ❖ Relaxants

- ❖ Rocuronium, Vecuronium, Pancuronium, Mivacurium (not atracurium)

## ❖ Sedatives

- ❖ Nitrous Oxide
- ❖ Isoflurane, Sevoflurane, Desflurane, Enflurane, Halothane
- ❖ Propofol
- ❖ Thiopentone, Midazolam

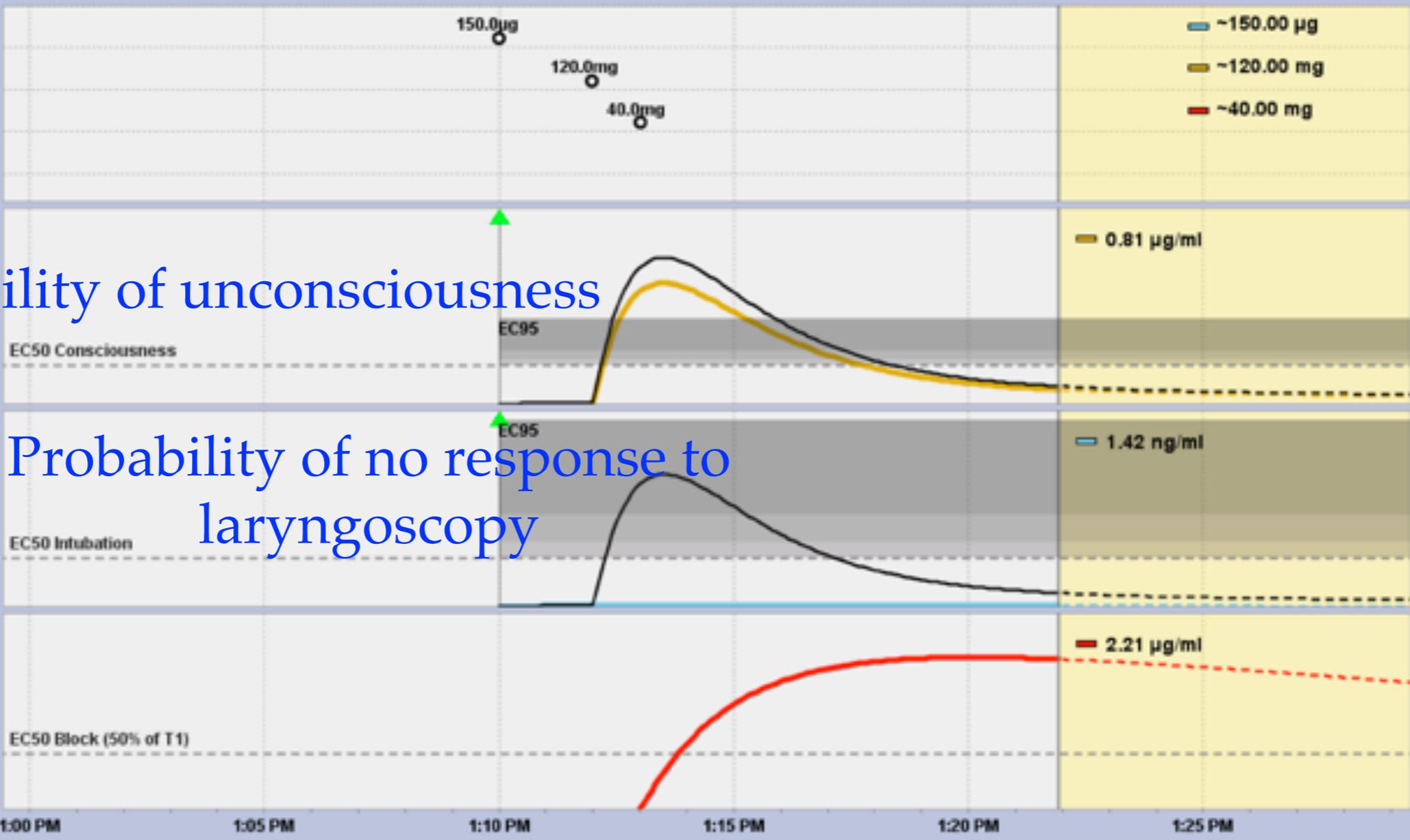
Therapy Protocol Device Setup Print End Case 40 yrs / M 80kg 170cm

Drug Selector  
Fentanyl (50 µg/mL)  
Propofol (10 mg/mL)  
Rocuronium (10 mg/mL)

Sedation  
Total Sedation  
Propofol Ce  
Entropy/BIS  
Interactions valid  
Interactions unknown

Analgesia  
Total Analgesia  
Fentanyl Ce  
PK Only

Relaxation  
Rocuronium Ce

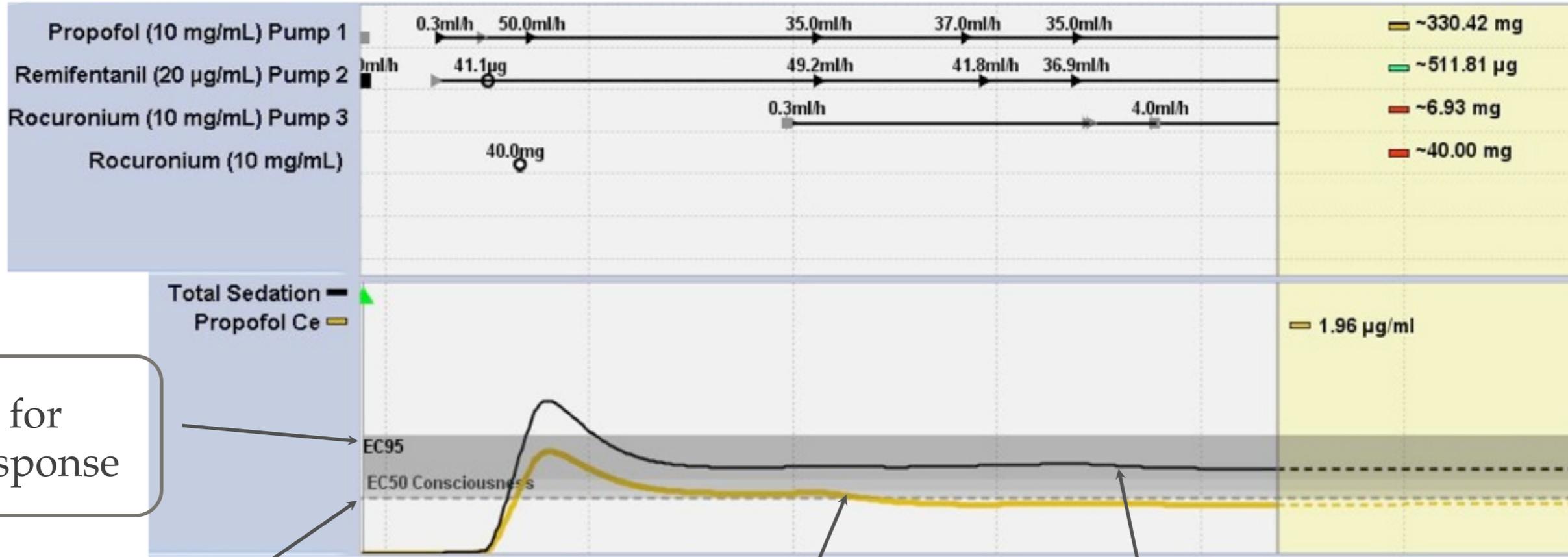


Probability of unconsciousness

Probability of no response to laryngoscopy

ATTENTION: Drug concentrations and effects are based on published models and do not represent actual measurements from this patient. More...

30 min [Navigation buttons]

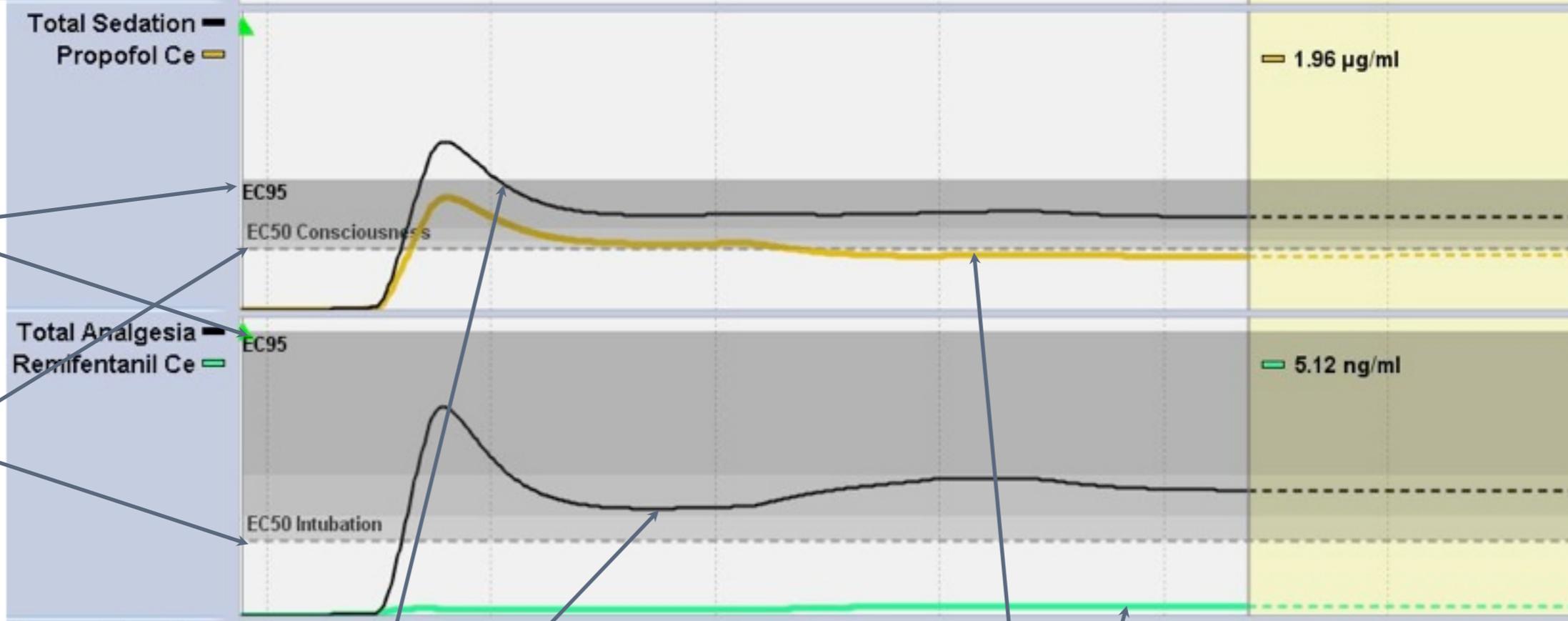
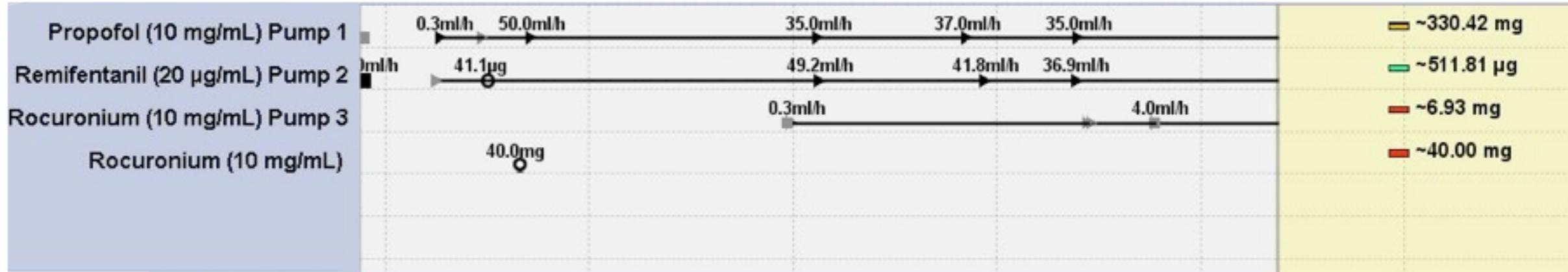


EC<sub>95</sub> for (non)response

EC<sub>50</sub> for response level 50% will respond (or not)

Combined effect

Effect of propofol alone



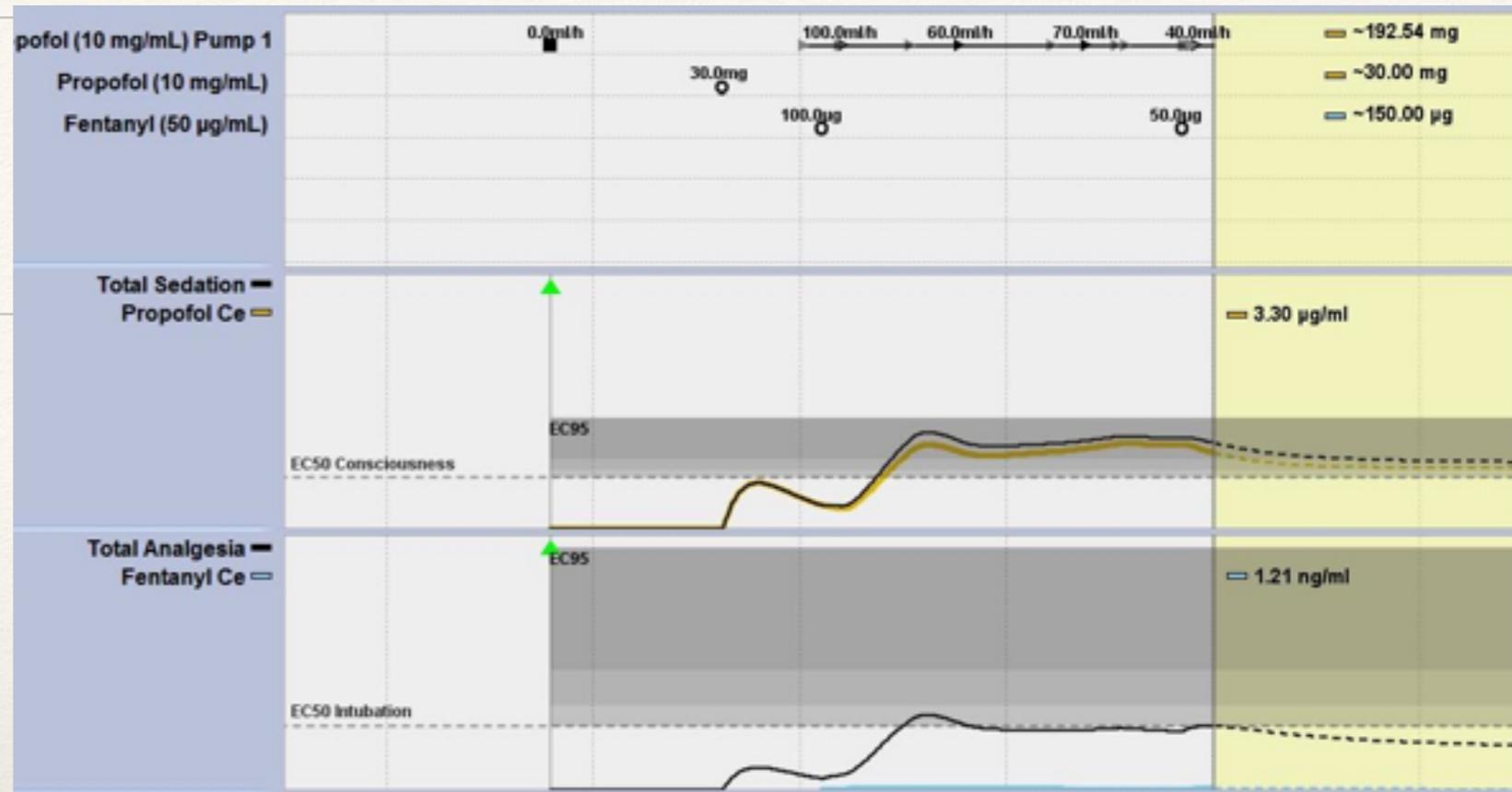
EC<sub>95</sub>

EC<sub>50</sub>

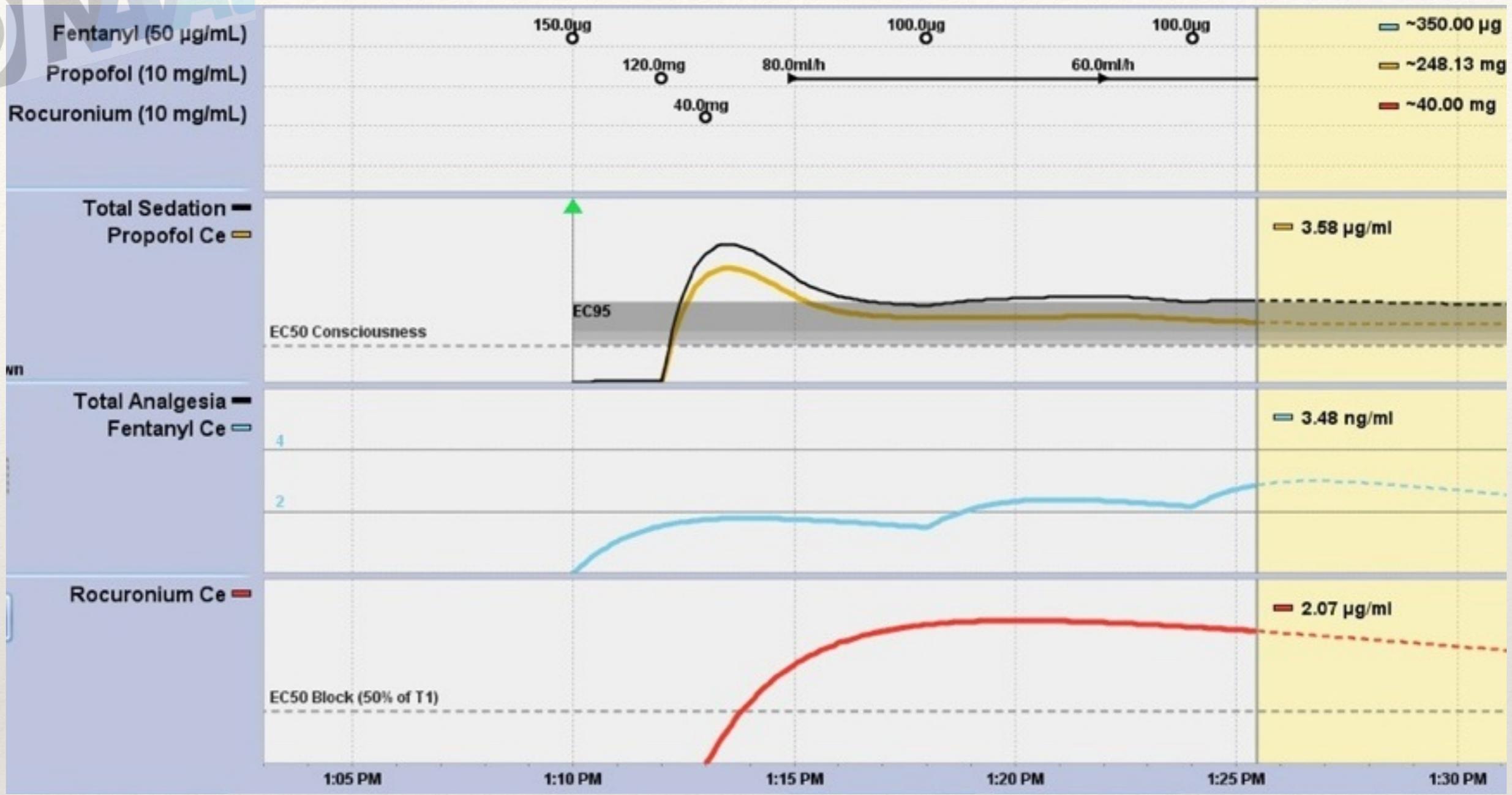
Combined effect

Individual drug

# “Manual TCI”



- ❖ User controls delivery
- ❖ Display shows trajectory
- ❖ Similar to TCI pumps in “manual” mode
- ❖ New drugs for TCI: relaxants, fentanyl, sufentanil
- ❖ Guide bolus and infusions



(Propofol infusion & fentanyl bolus)



# Titrating to effect:

- ❖ Adjust to match changing stimulus
- ❖ Other drugs equivalent to altered stimulus
  - ❖ alpha-2 agonists, morphine
- ❖ Find appropriate level
- ❖ And stay there



“The major strength of effect-site controlled TCI lies not in predicting the resulting hypnotic effect in the individual patient but rather in its ability to maintain the pharmacological condition once a predetermined clinical effect has been reached.”

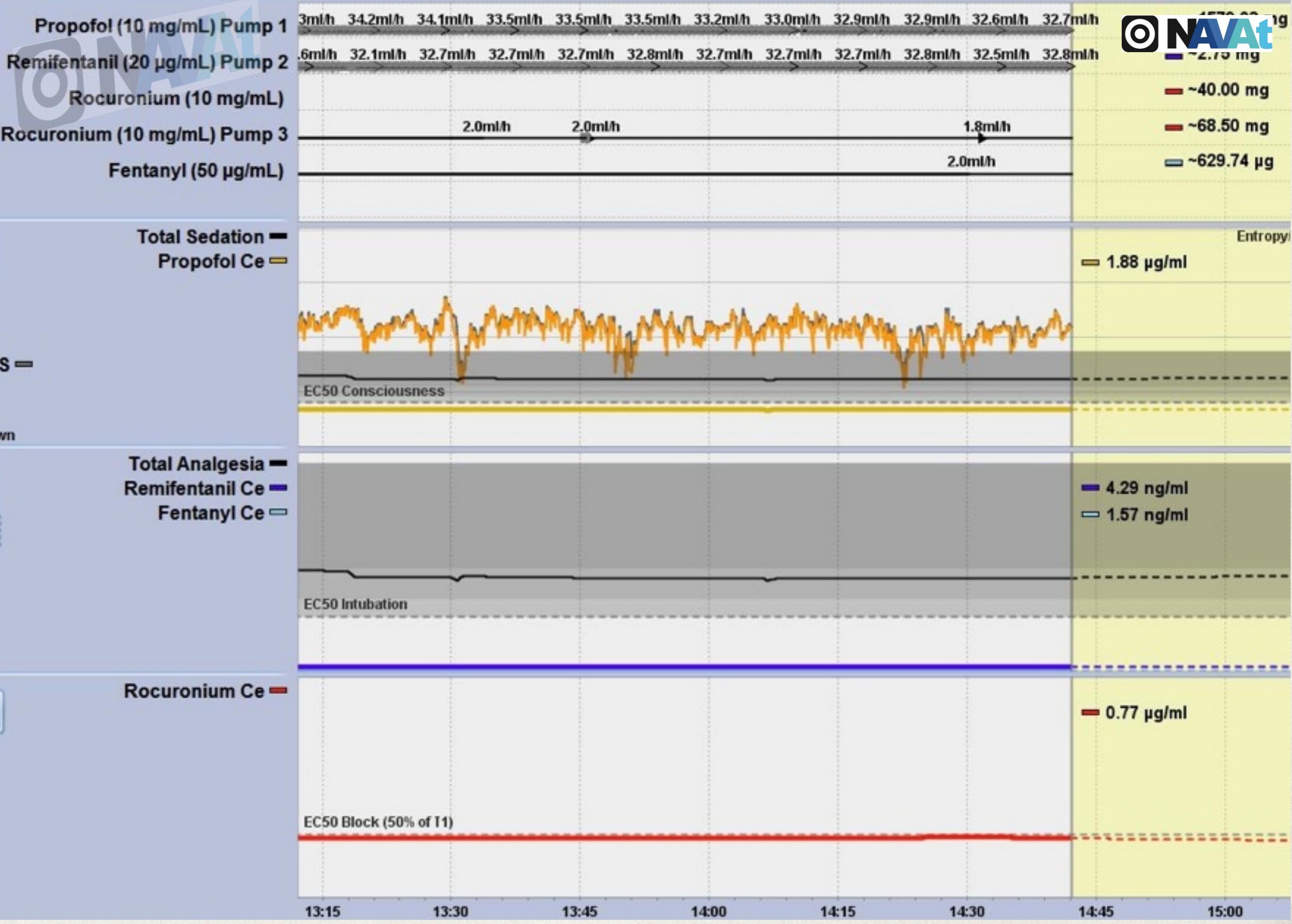
*British Journal of Anaesthesia* 104 (4): 452–8 (2010)  
doi:10.1093/bja/aeq028 Advance Access publication February 26, 2010

BJA

**Study of the time course of the clinical effect of propofol compared with the time course of the predicted effect-site concentration: performance of three pharmacokinetic–dynamic models**

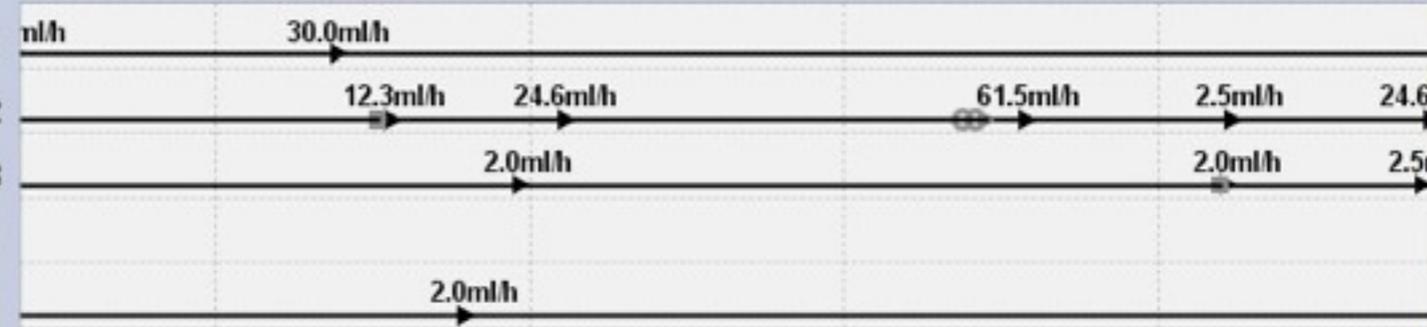
M. Coppens<sup>1</sup>, J. G. M. Van Limmen<sup>1</sup>, T. Schnider<sup>3</sup>, B. Wyler<sup>4</sup>, S. Bonte<sup>1</sup>, F. Dewaele<sup>2</sup>, M. M. R. F. Struys<sup>5, 6</sup> and H. E. M. Vereecke<sup>1\*</sup>





Drug Selector

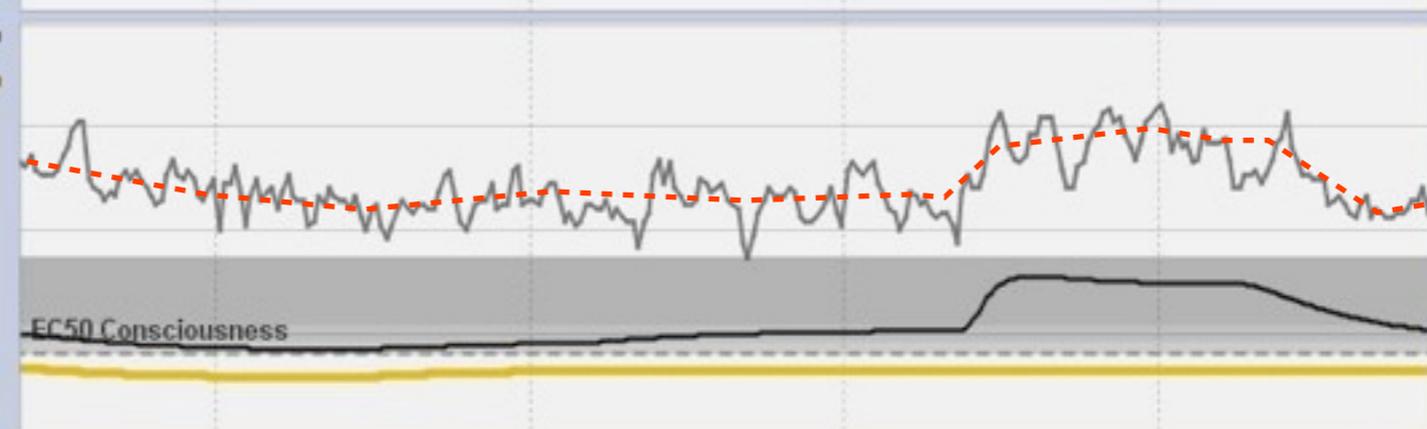
Propofol (10 mg/mL) Pump 1  
 Remifentanil (20 µg/mL) Pump 2  
 Rocuronium (10 mg/mL) Pump 3  
 Rocuronium (10 mg/mL)  
 Fentanyl (50 µg/mL)



~772.81 mg  
 ~1.31 mg  
 ~47.53 mg  
 ~40.00 mg  
 ~238.99 µg

Sedation

Total Sedation  
 Propofol Ce



1.80 µg/ml

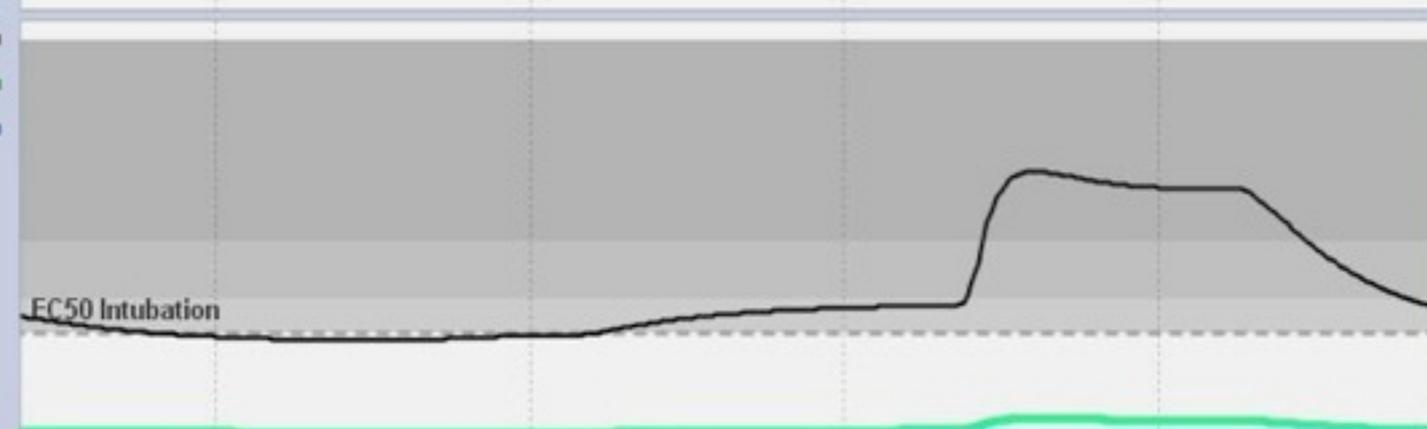
Entropy/BIS

RE SE BIS

Interactions valid  
 Interactions unknown

Analgesia

Total Analgesia  
 Remifentanil Ce  
 Fentanyl Ce



3.05 ng/ml  
 1.05 ng/ml

PK Only

Relaxation

Rocuronium Ce



1.02 µg/ml

13:00

13:10

13:20

13:30

13:40

13:50

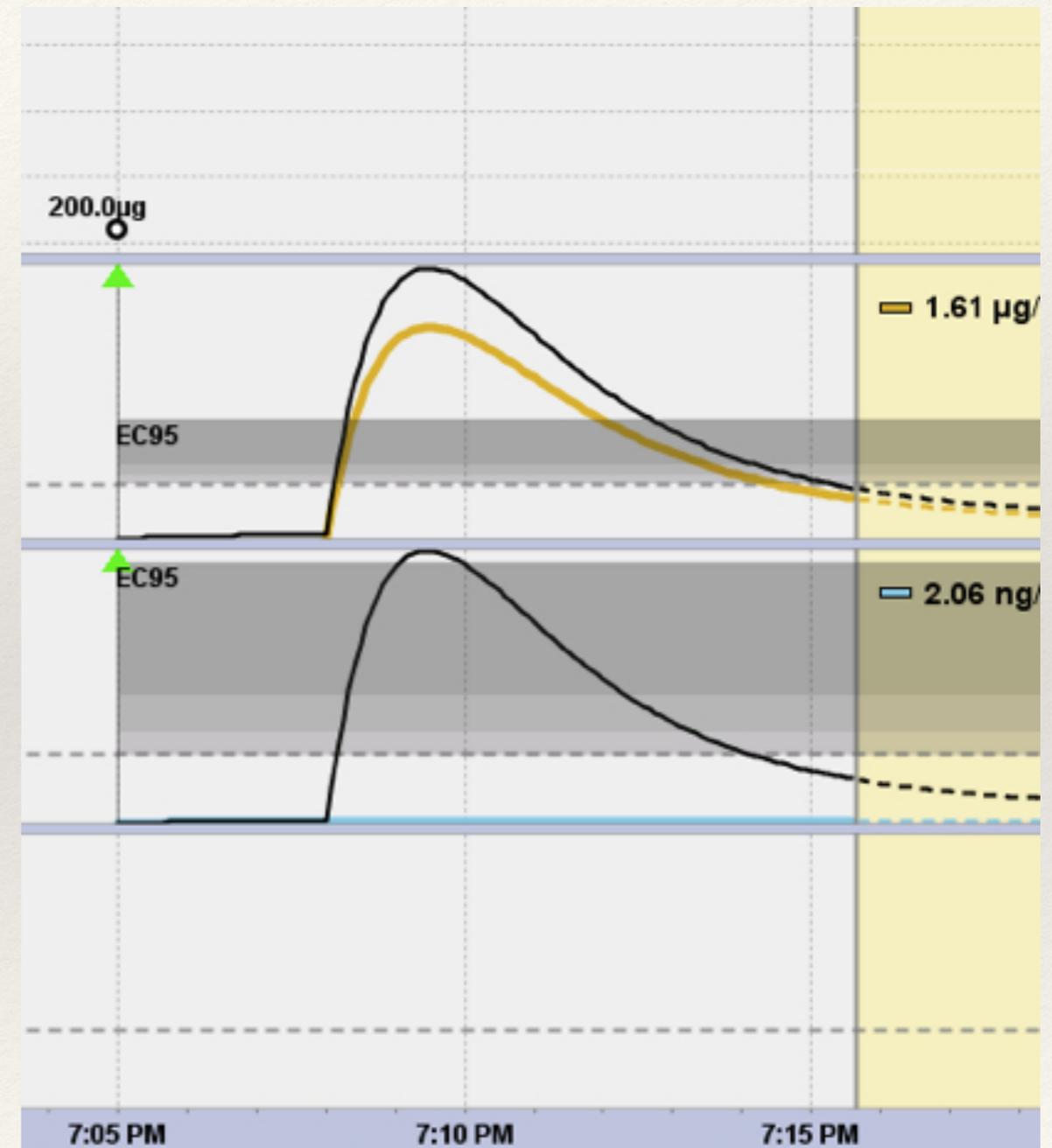
ATTENTION: Drug concentrations and effects are based on published models and do not represent actual measurements from this patient. More...

1 h

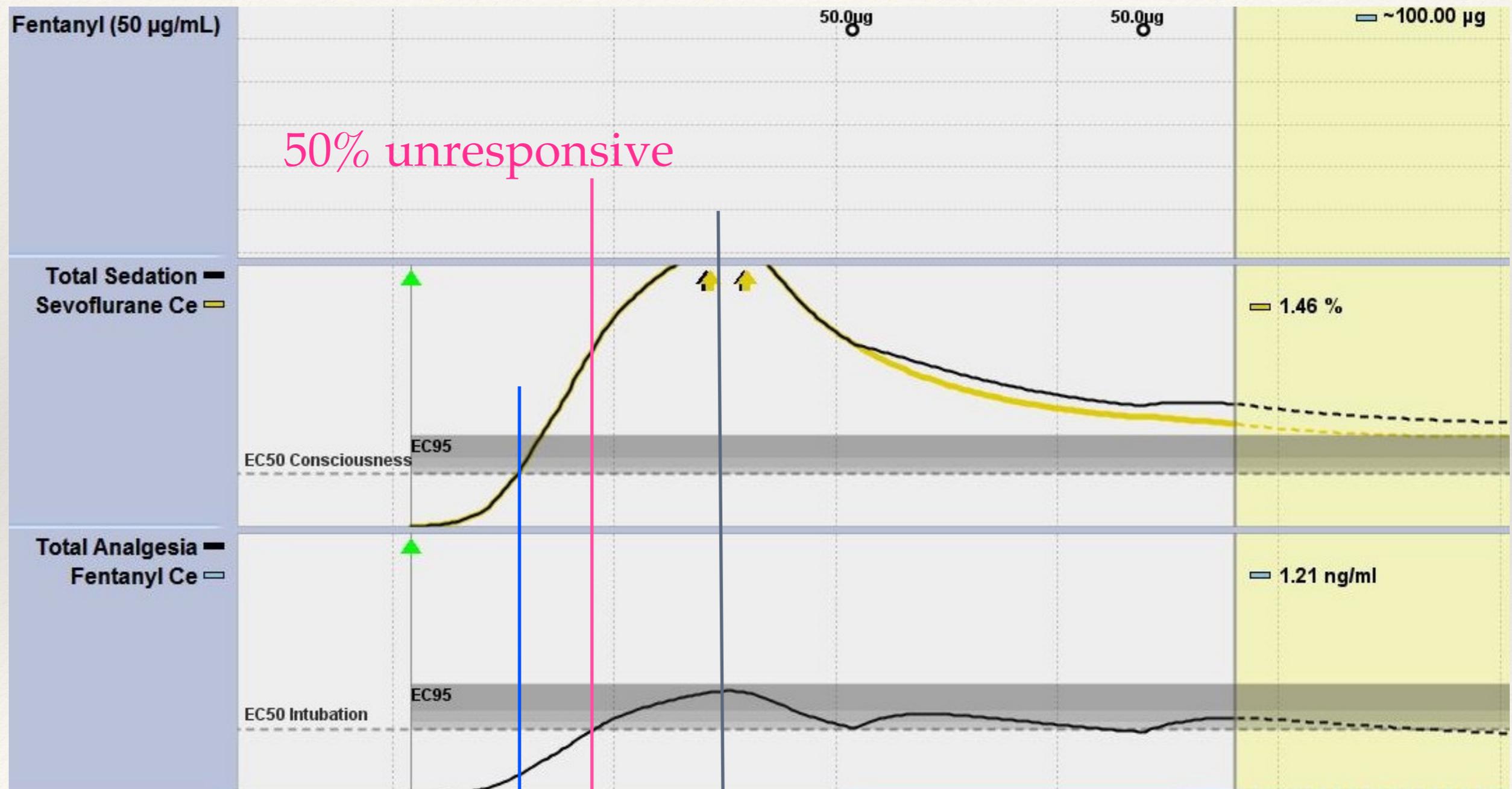


# IV Induction.....

- ❖ Length of effect of a propofol bolus
- ❖ The differential effect on hypnosis and response to noxious stimulus
- ❖ Why (even) more propofol may not be the best response to a “light” patient



# Inhalational induction...

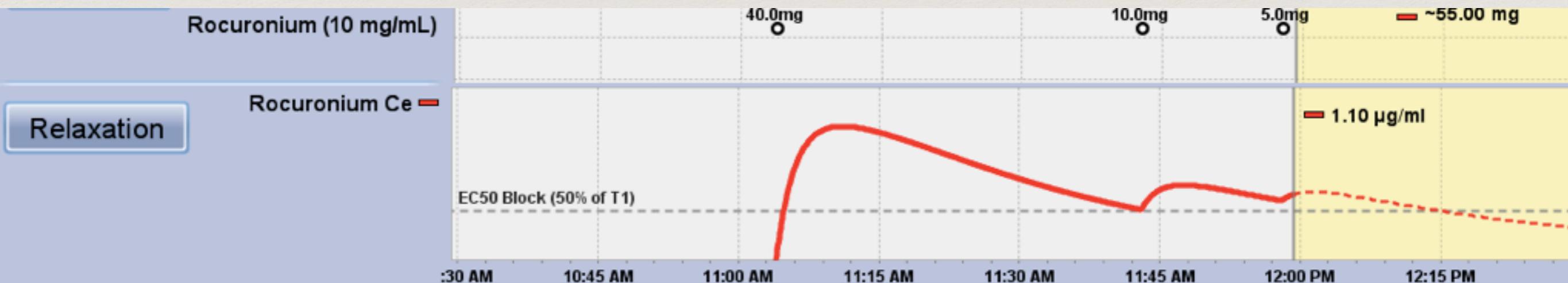


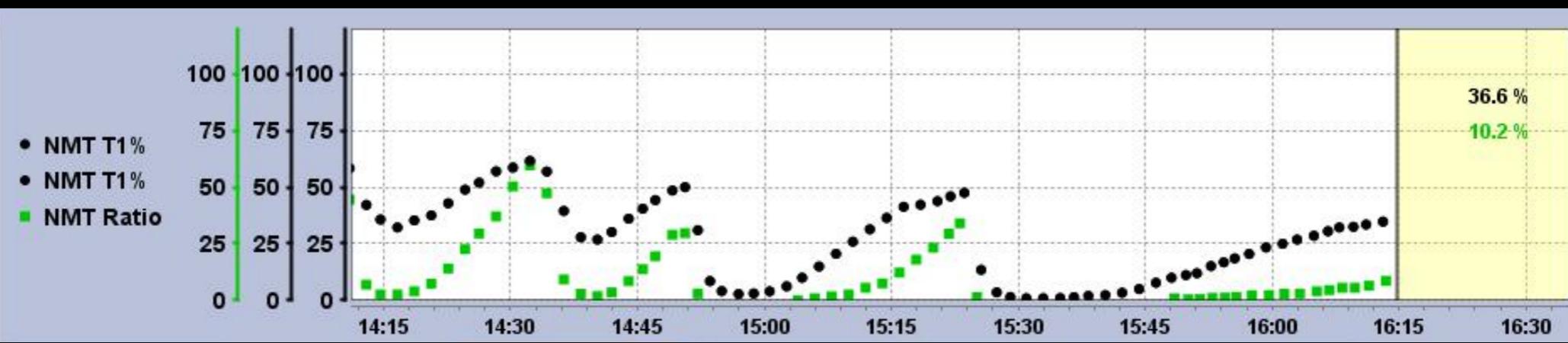
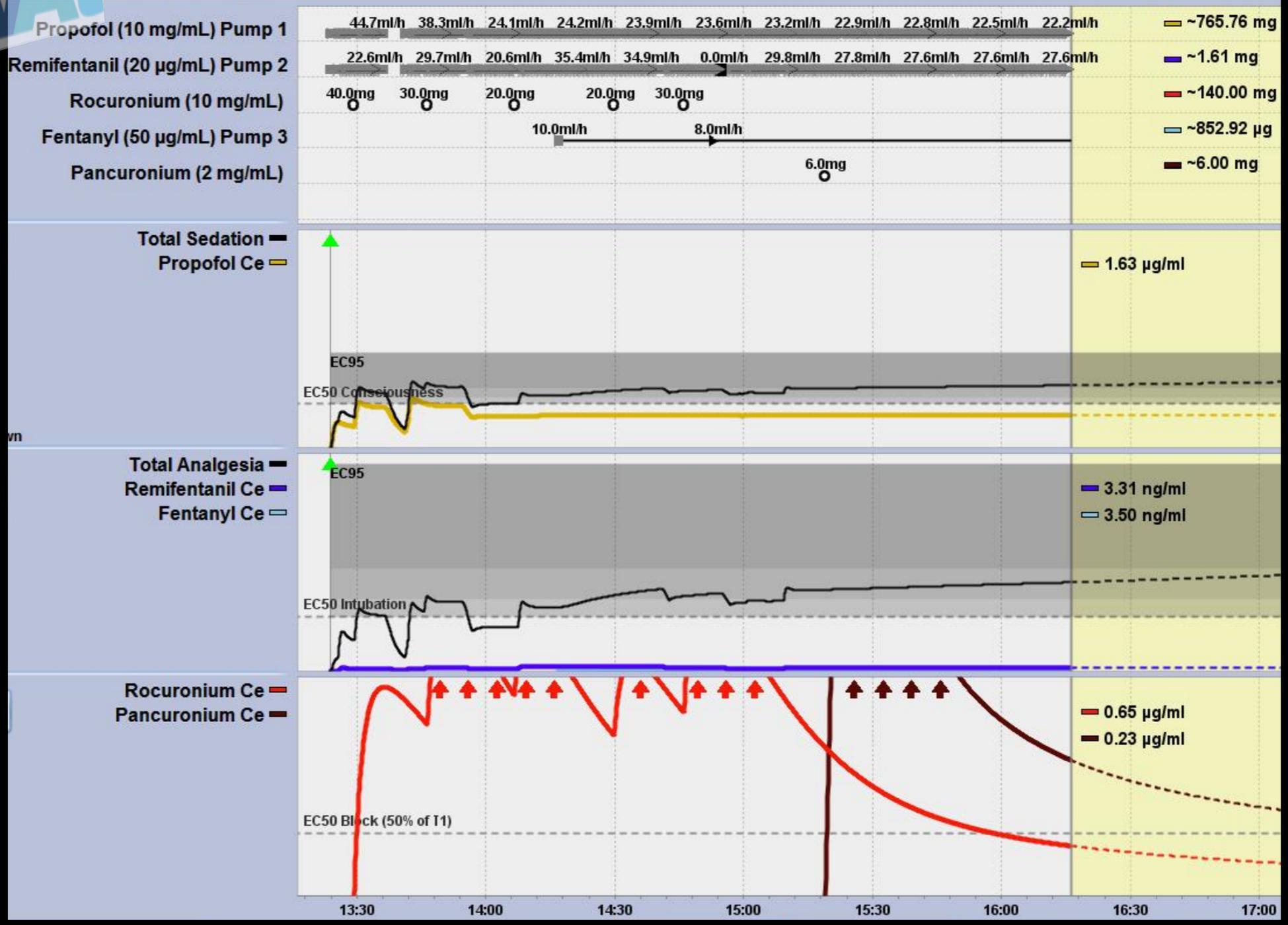
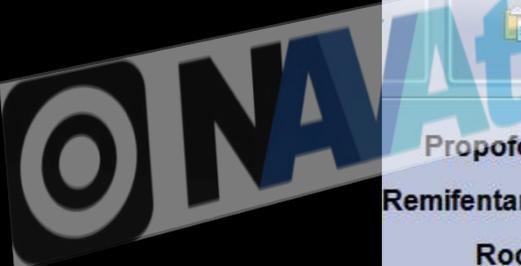
50% "asleep"

LMA inserted

# Relaxant kinetics

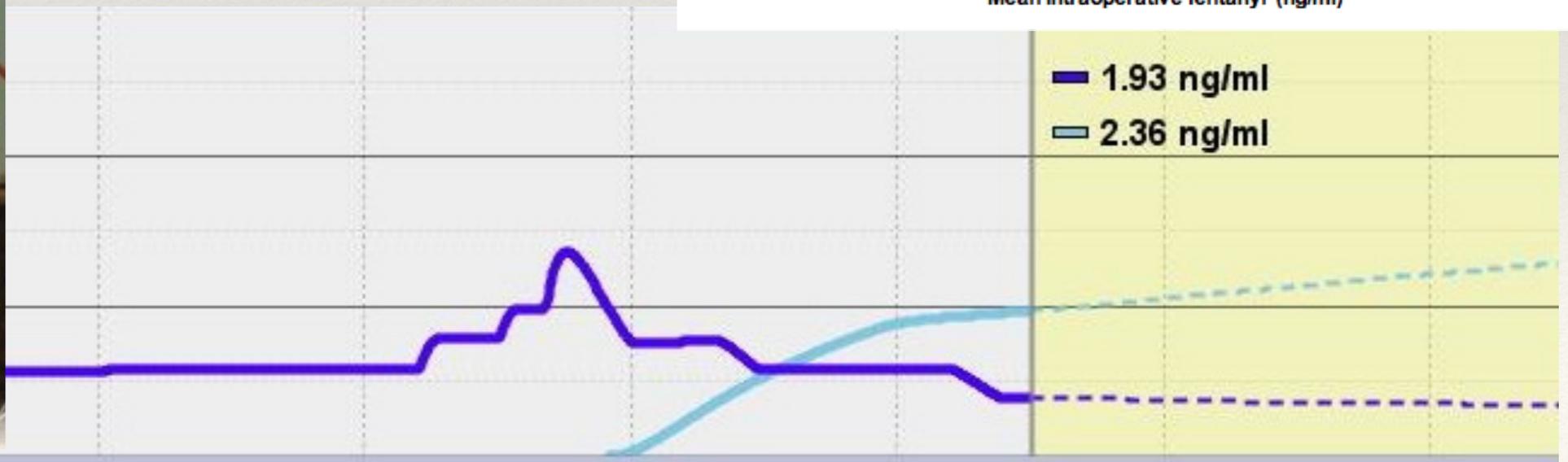
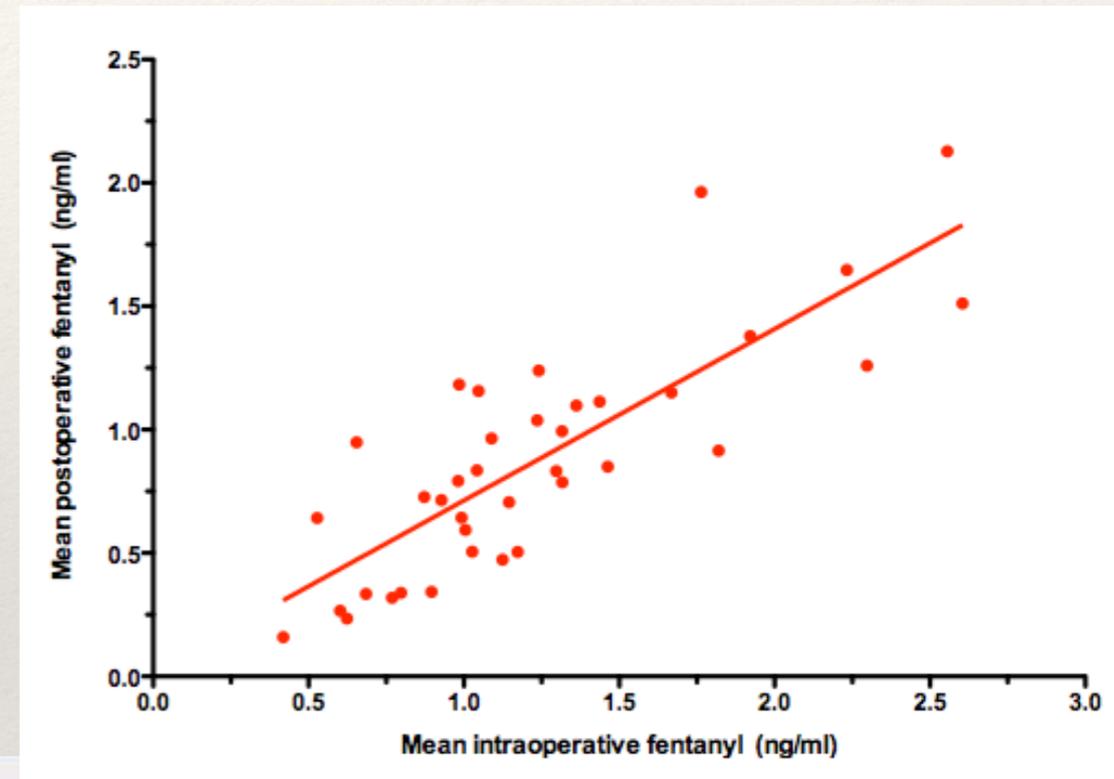
- ❖ Variability in response
  - ❖ intra-individual constant return of T2
- ❖ Dosing for surgical needs
  - ❖ time to peak effect (& return)
  - ❖ “smarter” timing at end of case

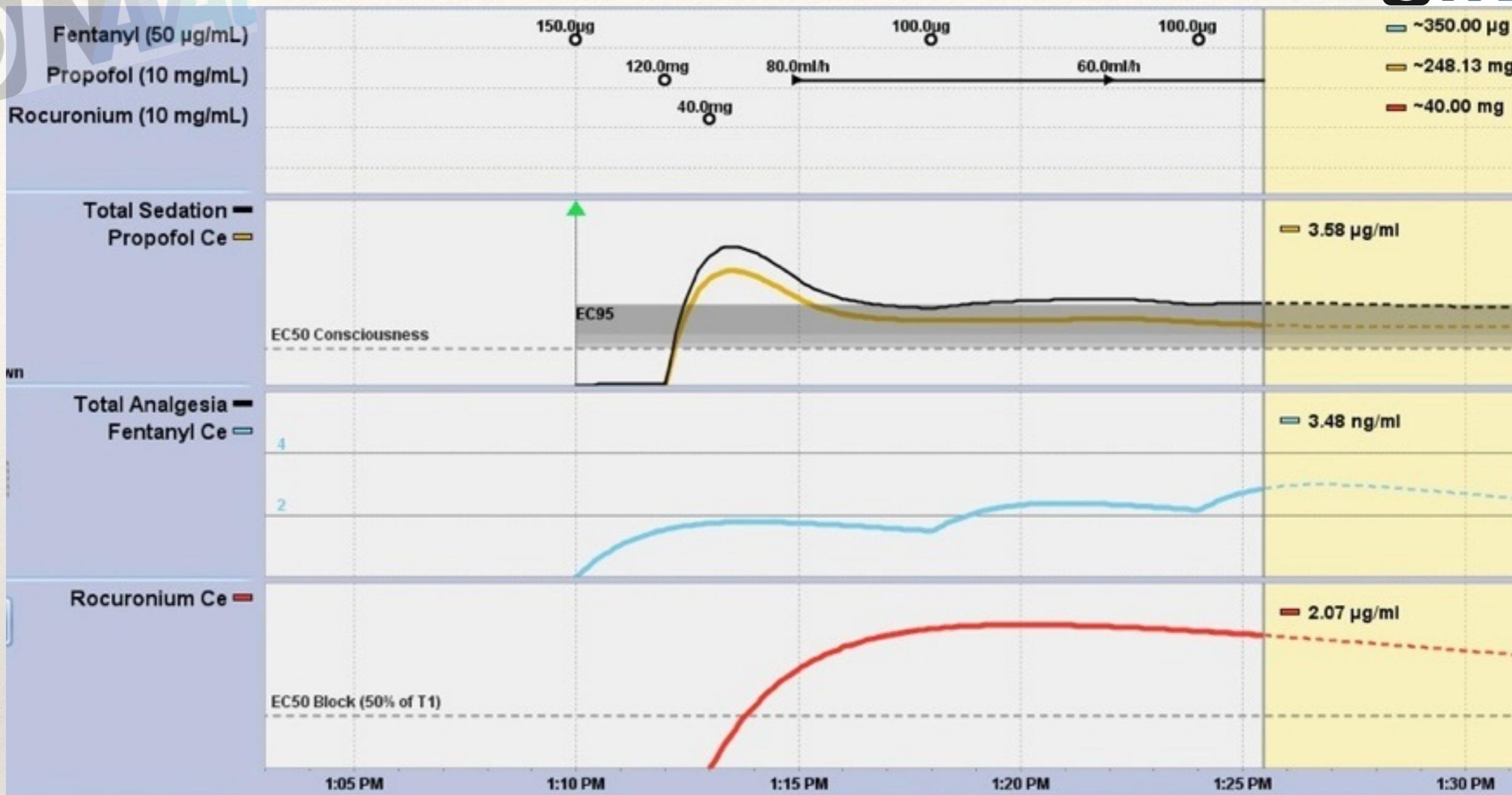




# Analgesics

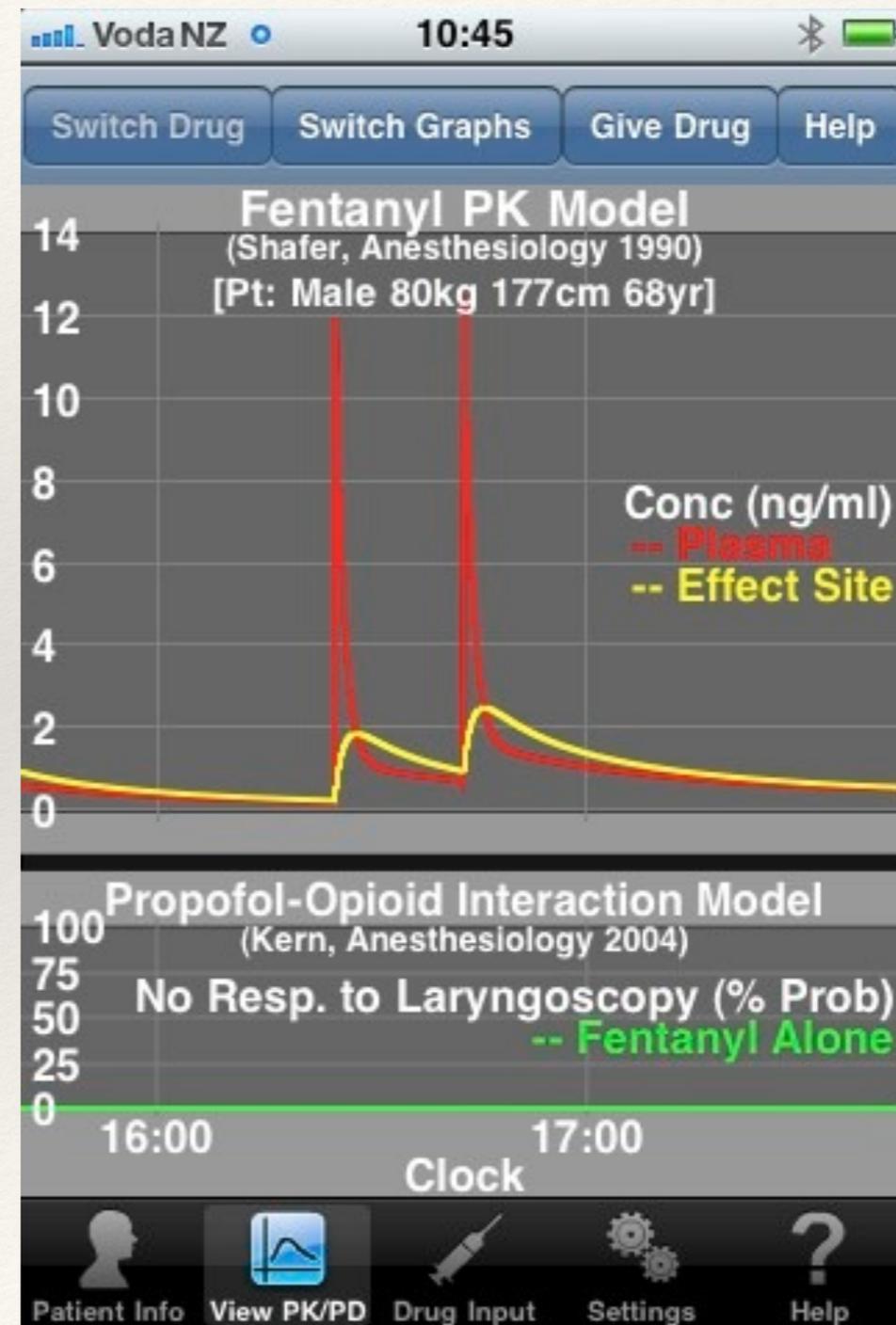
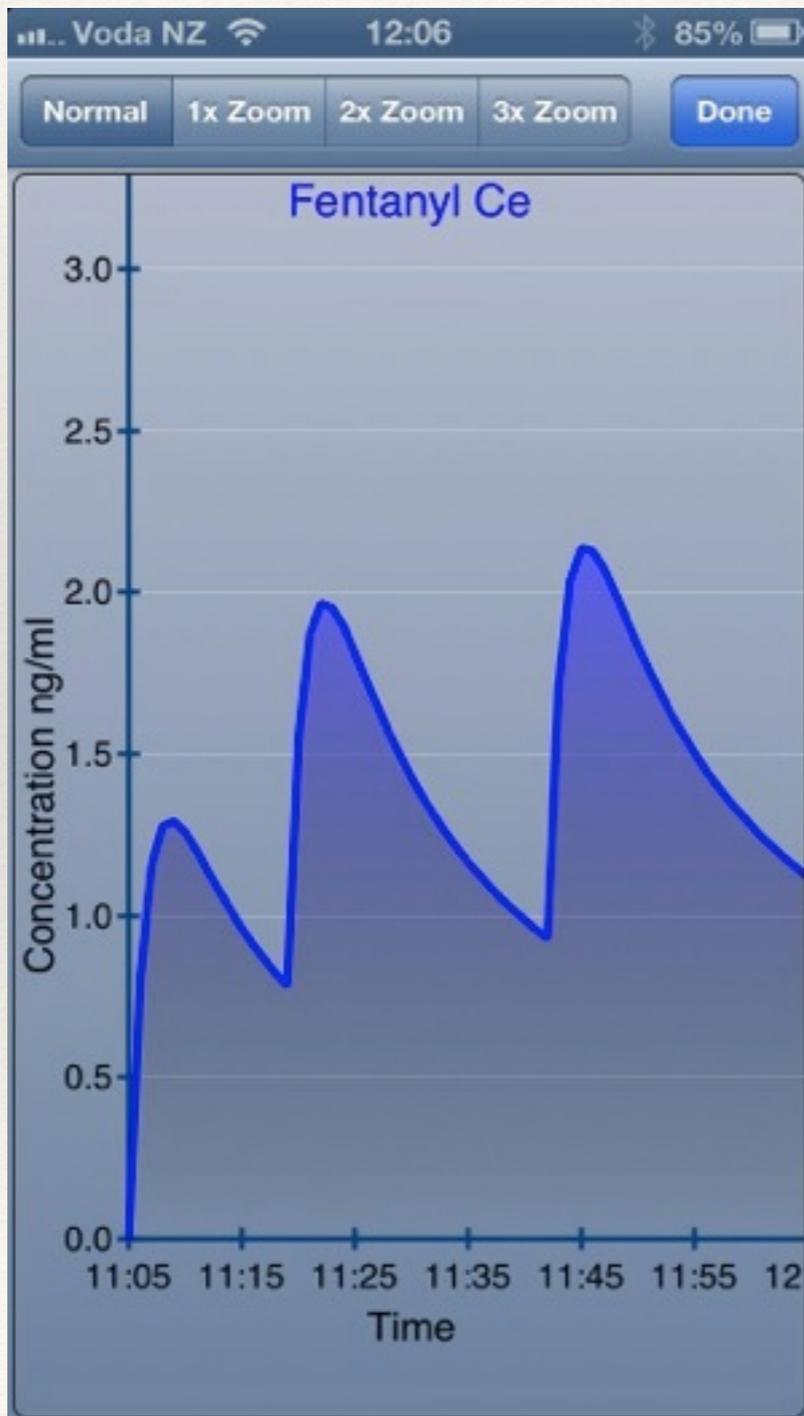
- ❖ Use intraoperative analgesic needs to estimate postoperative requirement
- ❖ Often infuse fentanyl (4 pumps)





Seeing fentanyl effect site profile allows better matching of dosing to clinical effect

# “App guided” fentanyl dosing

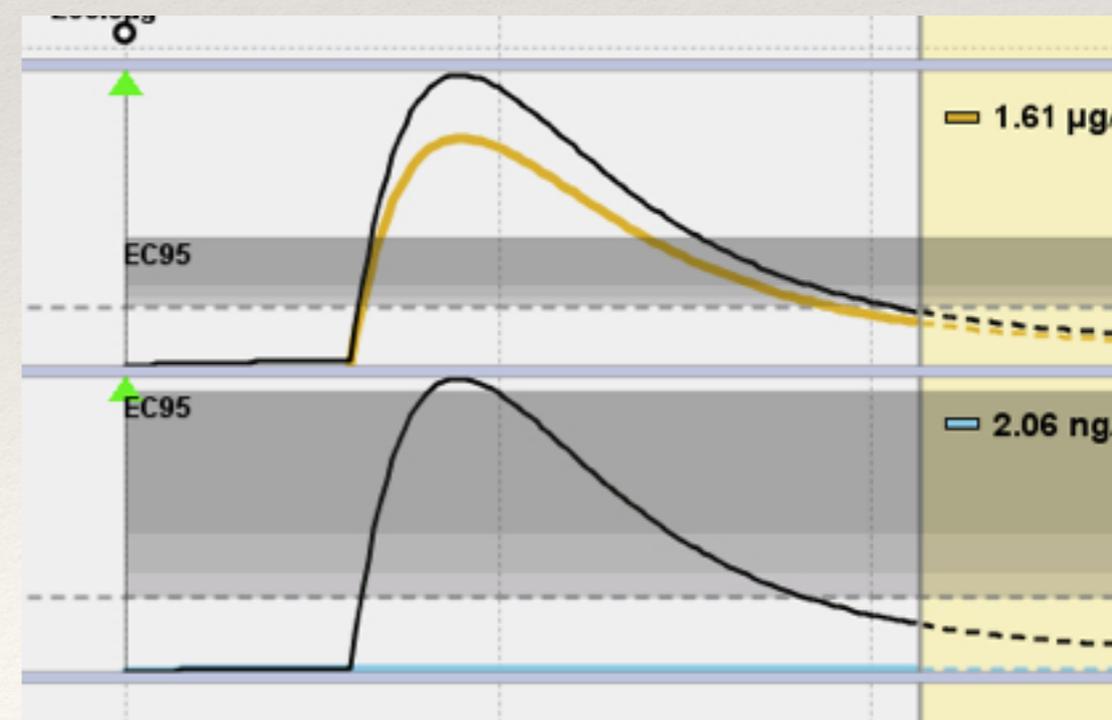
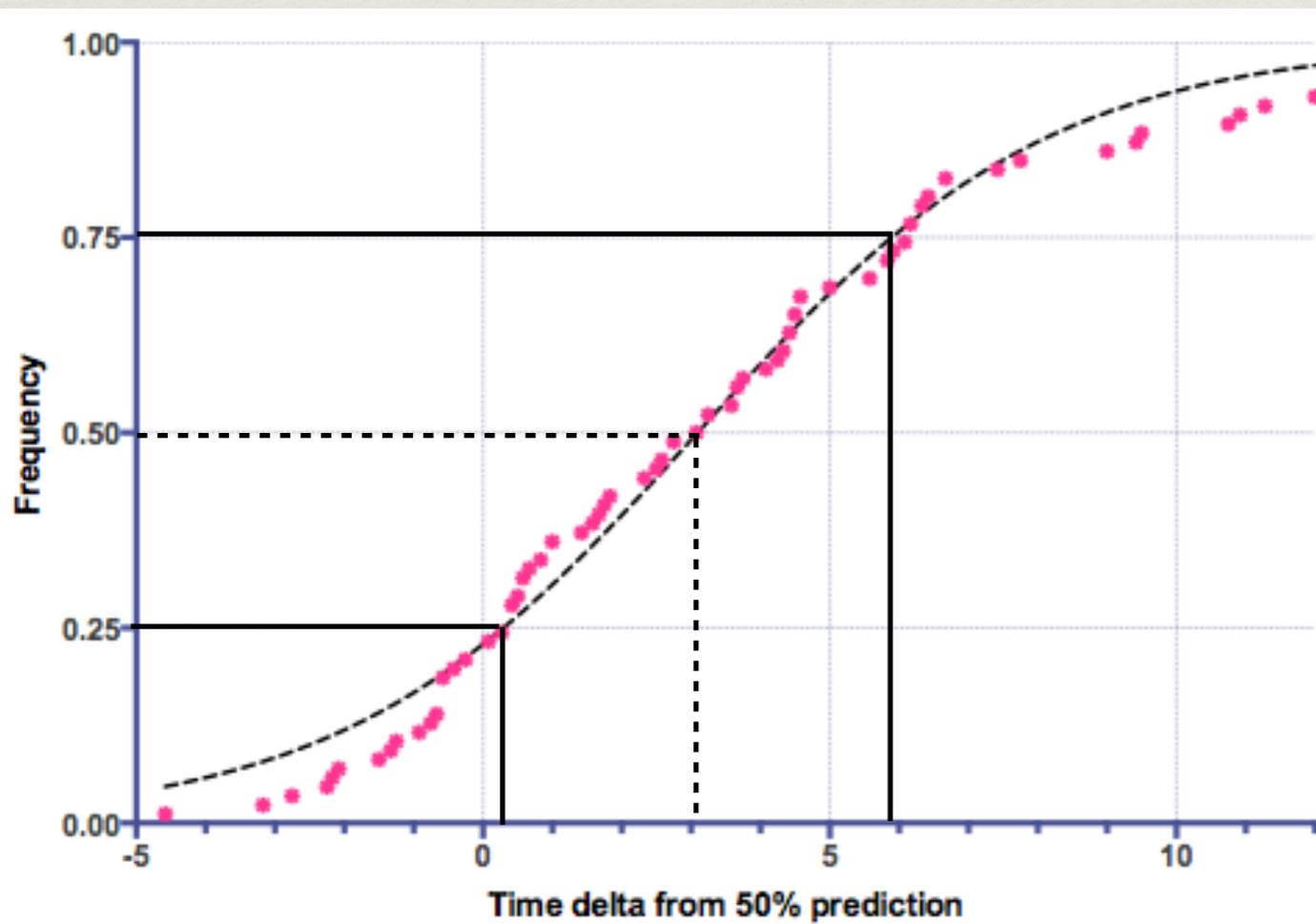


# Controlled recovery

- ❖ “90% wake within 1 min of EC50”
- ❖ Tailor drug washout

## An Evaluation of Remifentanyl-Sevoflurane Response Surface Models in Patients Emerging from Anesthesia: Model Improvement Using Effect-Site Sevoflurane Concentrations

Ken B. Johnson, MD\*  
 Noah D. Syroid, MS\*  
 Dhanesh K. Gupta, MD†  
 Sandeep C. Manyam, PhD‡  
 Nathan L. Pace, MD\*  
 Cris D. LaPierre, BS\*  
 Talmage D. Egan, MD\*  
 Julia L. White, RN\*  
 Diane Tyler, RN\*  
 Dwayne R. Westenskow, PhD\*



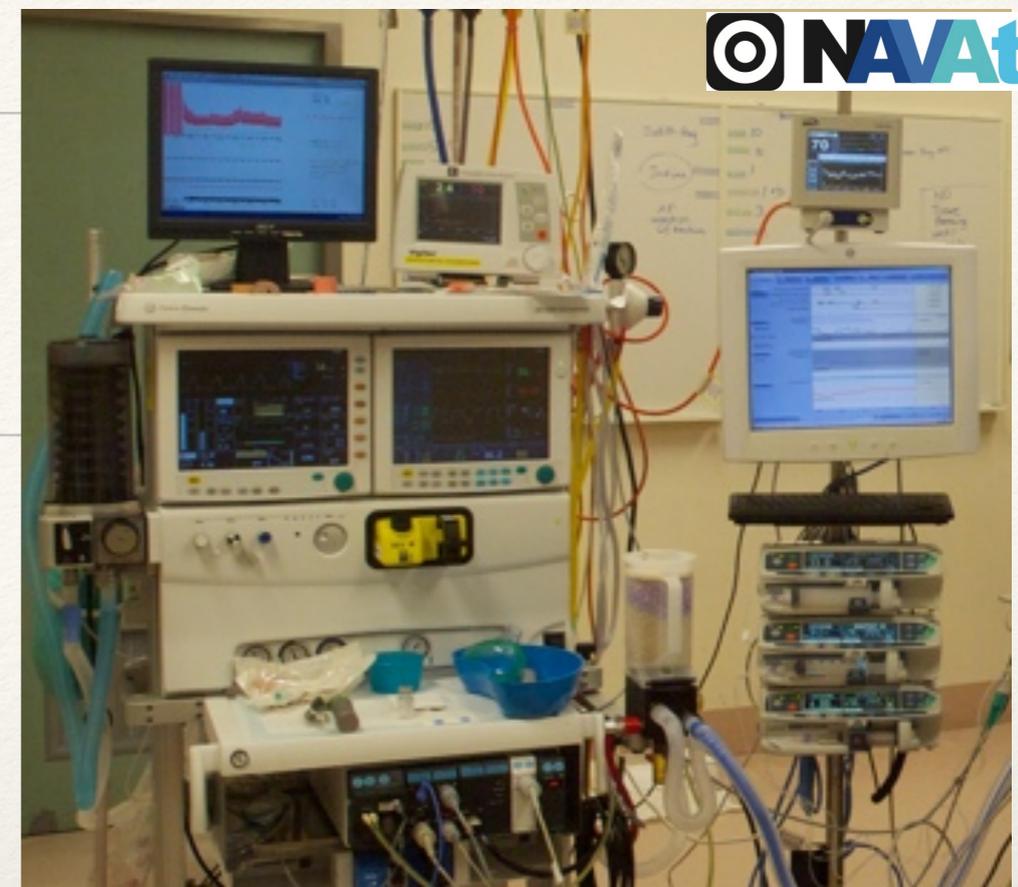
# What can you expect from Navigator?

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- ❖ A great demonstration of what's going on
- ❖ Excellent teaching tool
- ❖ Principles can be applied in other settings
- ❖ Can alter and adapt (?improve) anaesthetic technique
- ❖ Deal with inter-patient variability - *titration tool*
  - ❖ MAC is not a magic number
- ❖ Has helped me develop my technique (iv & volatile)

# Limitations

- ❖ “Only” three pumps
- ❖ Time based display (vs isobologram)
- ❖ Inhalational data uses only end-tidal
  - ❖ forward predictions less accurate and less responsive to changes
- ❖ No propofol / inhalational interaction (+/- opioid)
- ❖ Need to alternate modes to see opioid levels and effects
  - ❖ Alfentanil scale useless, PK scales fixed
- ❖ Not all sedative / analgesic drugs modelled





# Automated delivery of vapor is not new!

*Br. J. Anaesth.* (1986), 58, 555-562

## CONTROL OF END-TIDAL HALOTHANE CONCENTRATION

*Part A: Anaesthesia Breathing System and Feedback Control of Gas Delivery*

D. R. WESTENSKOW, A. M. ZBINDEN, D. A. THOMSON  
AND B. KOHLER

*J. Anaesth.* (1983), 55, 1053

## SERVO-CONTROLLED CLOSED-CIRCUIT ANAESTHESIA

*A method for the automatic control of anaesthesia produced by a volatile agent in oxygen*

J. A. S. ROSS, R. T. WLOCH, D. C. WHITE AND D. W. HAWES

*Br. J. Anaesth.* (1984), 56, 1417

## COMPUTER ASSISTANCE IN THE CONTROL OF DEPTH OF ANAESTHESIA†

R. T. CHILCOAT, J. N. LUNN, AND W. W. MAPLESON

SUMMARY

*Br. J. Anaesth.* (1983), 55, 1061

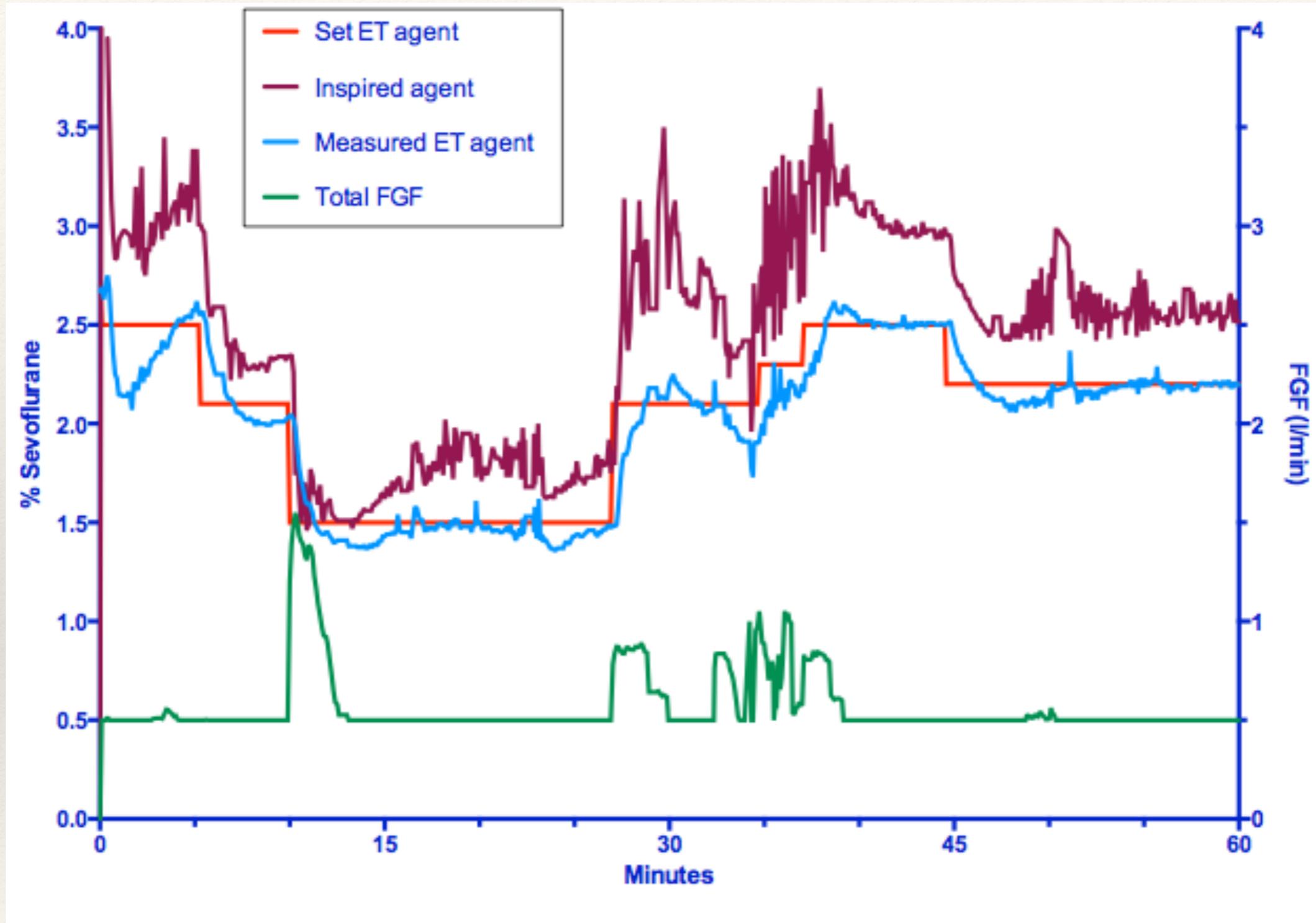
## UPTAKE OF ISOFLURANE DURING CLINICAL ANAESTHESIA

*Servo-control of liquid anaesthetic injection into a closed-circuit breathing system*

A. C. O'CALLAGHAN, D. W. HAWES, J. A. S. ROSS, D. C. WHITE AND R. T. WLOCH

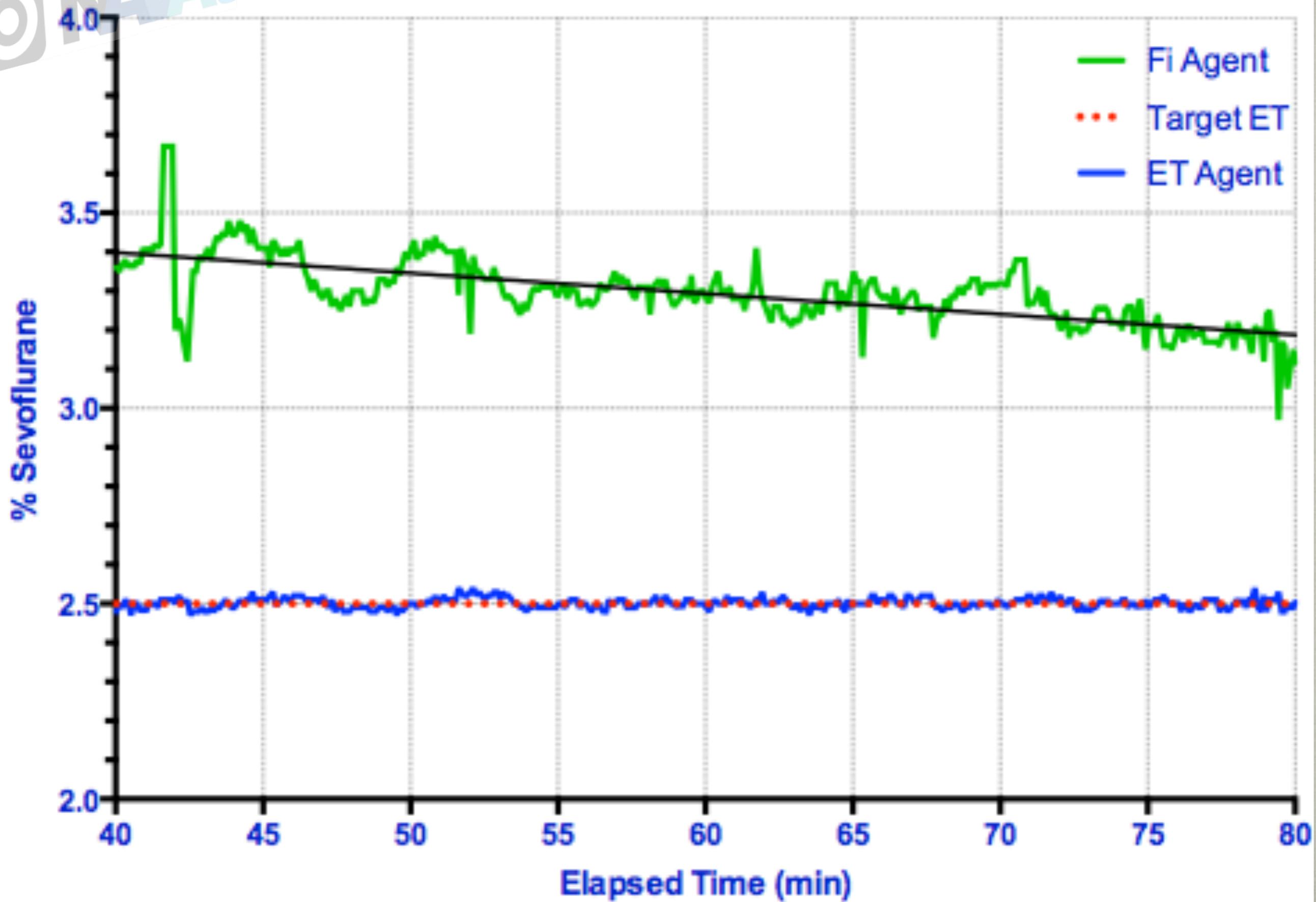


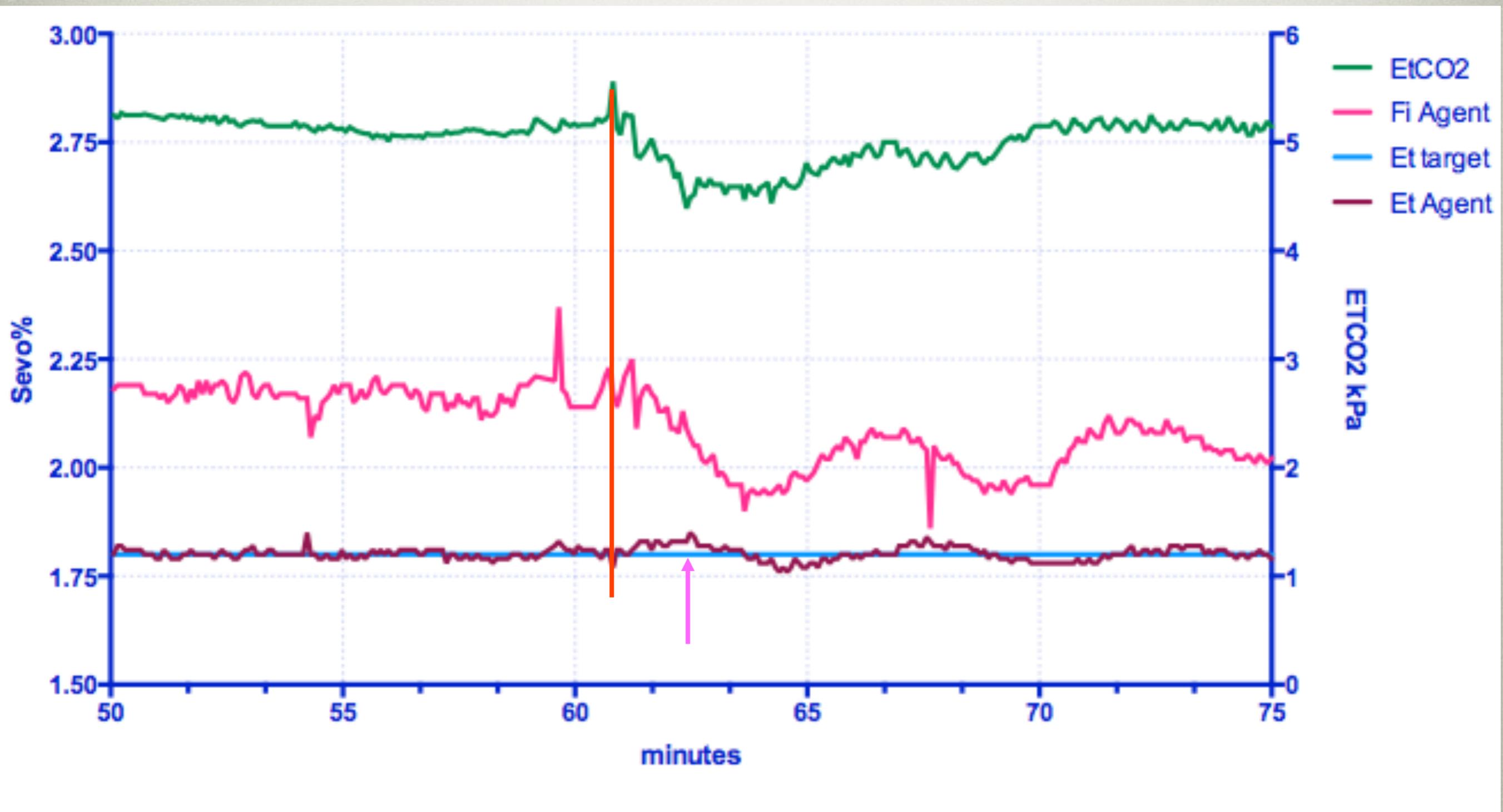
# Automated systems are good at controlling vapour



What else can we learn from them?







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**Continuous Monitoring of Alveolar and Inspiratory Concentrations of Anesthetic and Respiratory Gases Is Safe, Simple, and Cost-Effective**

*John W. Severinghaus, MD*

---

Severinghaus JW. Continuous monitoring of alveolar and inspiratory concentrations of anesthetic and respiratory gases is safe, simple, and cost-effective.

J Clin Monit 1987;3:123

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**Continuous Monitoring of Alveolar and Inspiratory Concentrations of Anesthetic and Respiratory Gases Is Difficult and Potentially Unsafe**

*M. K. Sykes, MA, MB, B Chir, FFARCS, FFARACS (Hon)*

---

Sykes MK. Continuous monitoring of alveolar and inspiratory concentrations of anesthetic and respiratory gases is difficult and potentially unsafe.

J Clin Monit 1987;3:116-122



- ❖ I can do better than some dumb machine

- ❖ Trainees need to learn to give a proper anaesthetic otherwise they won't understand volatile kinetics

- ❖ What if it breaks?



- ❖ It's an expensive new toy

*No you can't.*

*A machine is at least as accurate and more reliable*

*What is a proper anaesthetic?*

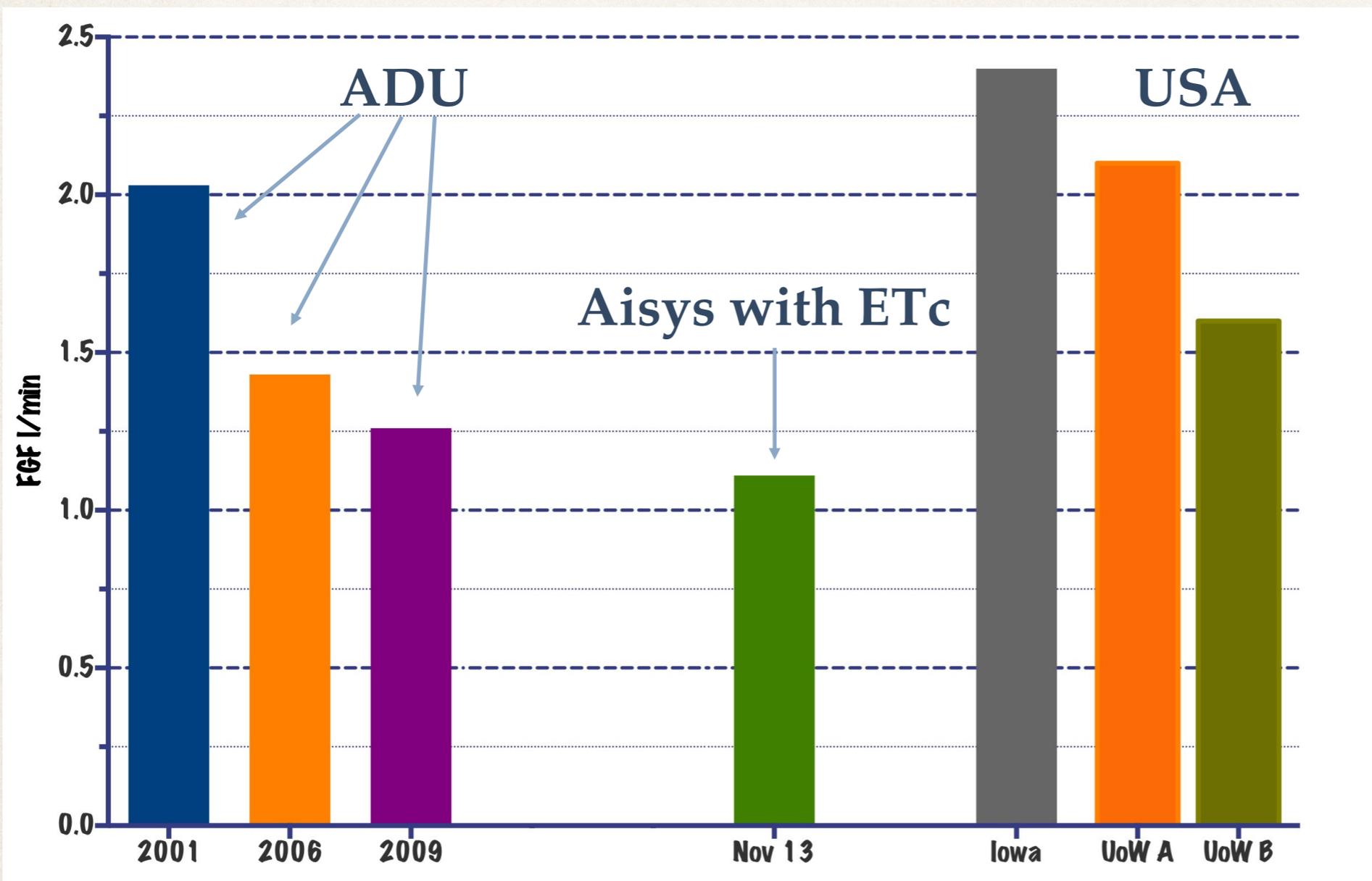
*Do you insist on ml/hr propofol when TCI is available?*

*Watching the automated controller teaches more about kinetics than learning a recipe!*

*Yes the ability to give a "manual" anaesthetic is an essential skill*

*Which reduces FGF rates and saves money*





} = €100,000 pa

} = 100 tonnes CO<sub>2</sub> pa

30 OR & 28,500 cases

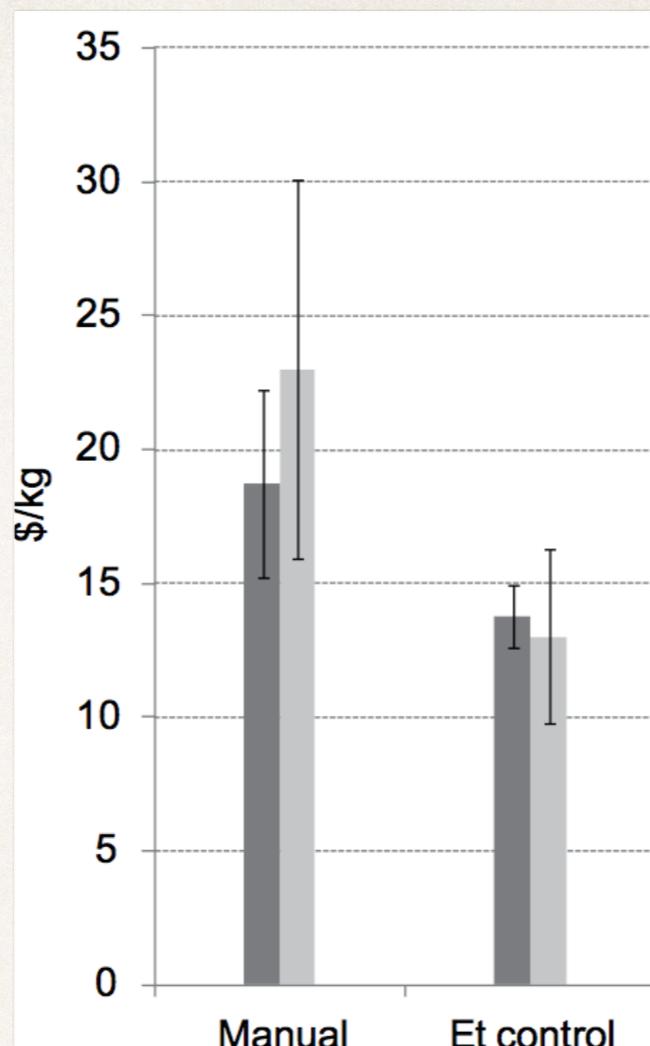
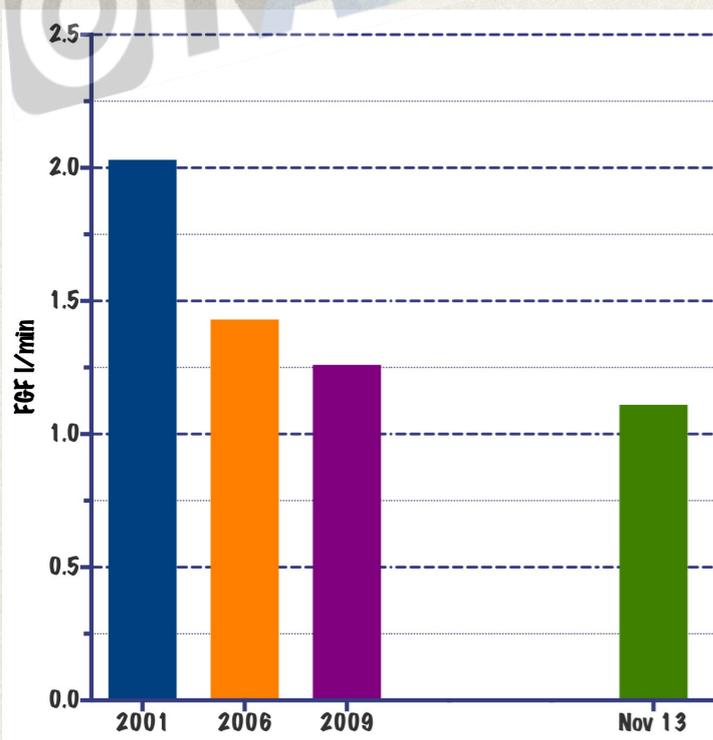


FIGURE 5: Cost (dark grey) and 100-year global warming potential (light grey) per hour  $\pm$  95% confidence interval in the manual versus Et control phases. Et control=automated control of end-tidal gases.

Anaesth Intensive Care 2013; 41: 95-101

## Financial and environmental costs of manual versus automated control of end-tidal gas concentrations

S. TAY\*, L. WEINBERG†, P. PEYTON‡, D. STORY§, J. BRIEDIS\*\*

Department of Anaesthesia, Northern Hospital, Melbourne, Victoria, Australia

Cost reduced 27%

GWP down 44%

J Clin Monit Comput (2014) 28:117–121

DOI 10.1007/s10877-013-9516-8

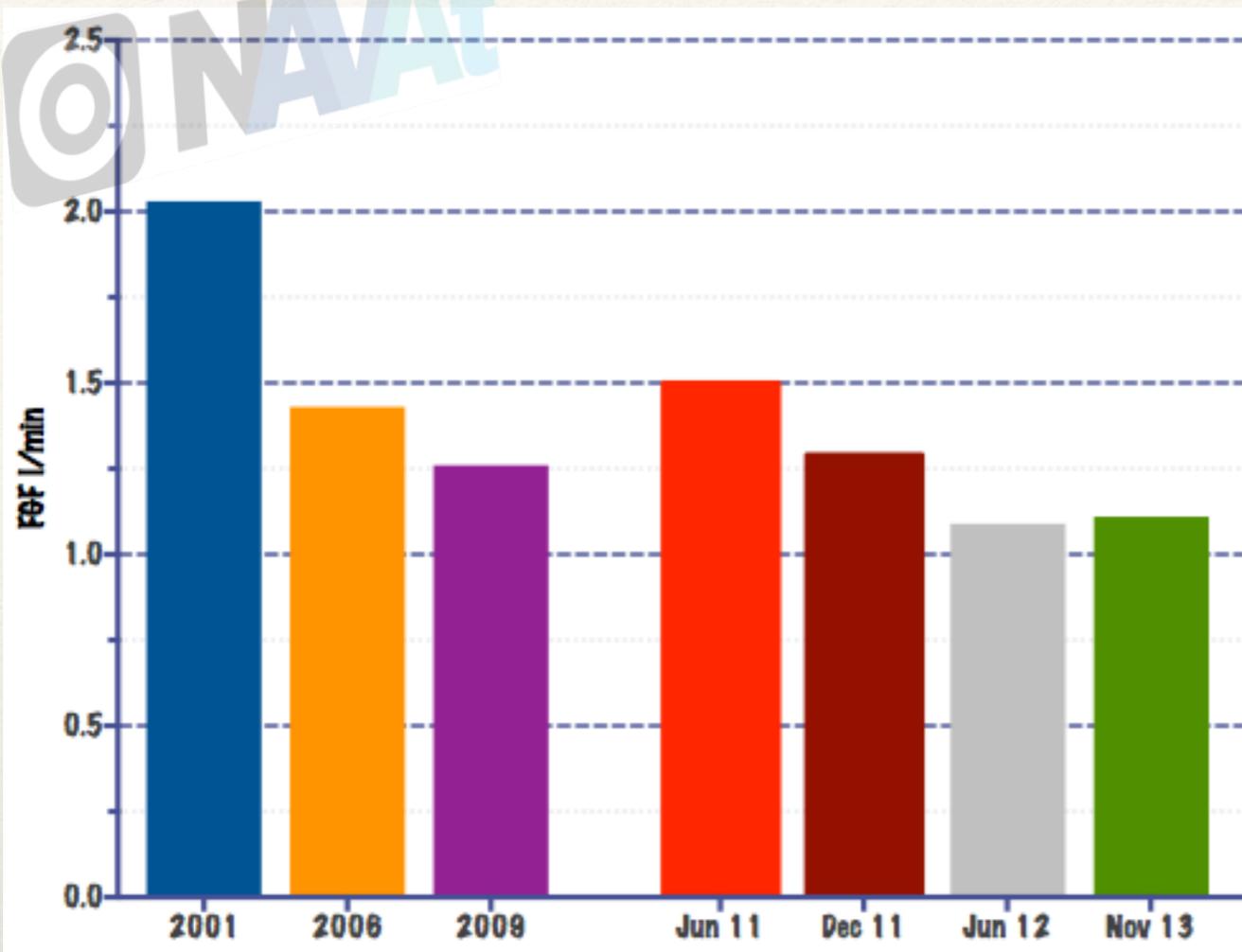
ORIGINAL RESEARCH

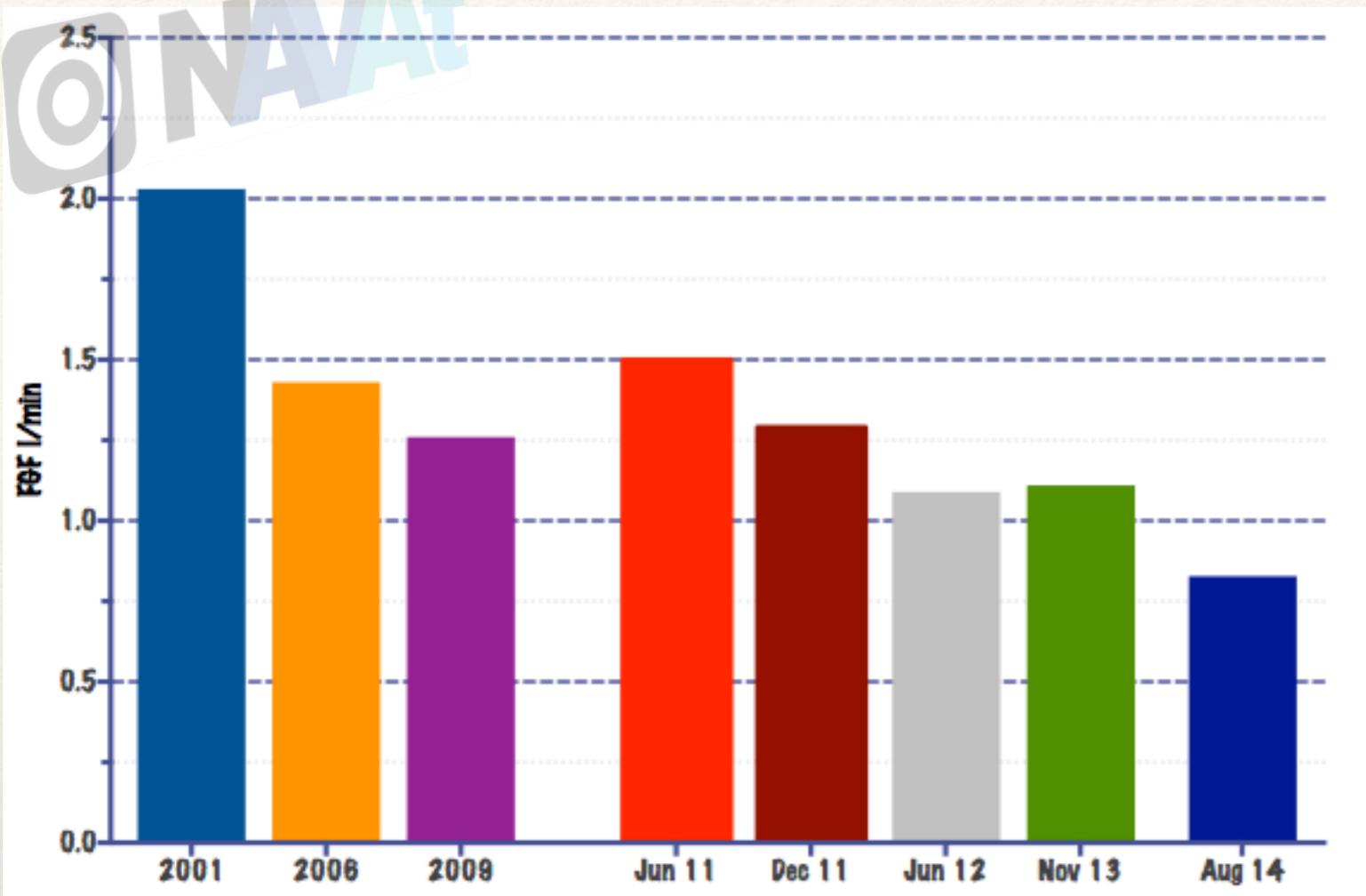
### End-tidal versus manually-controlled low-flow anaesthesia

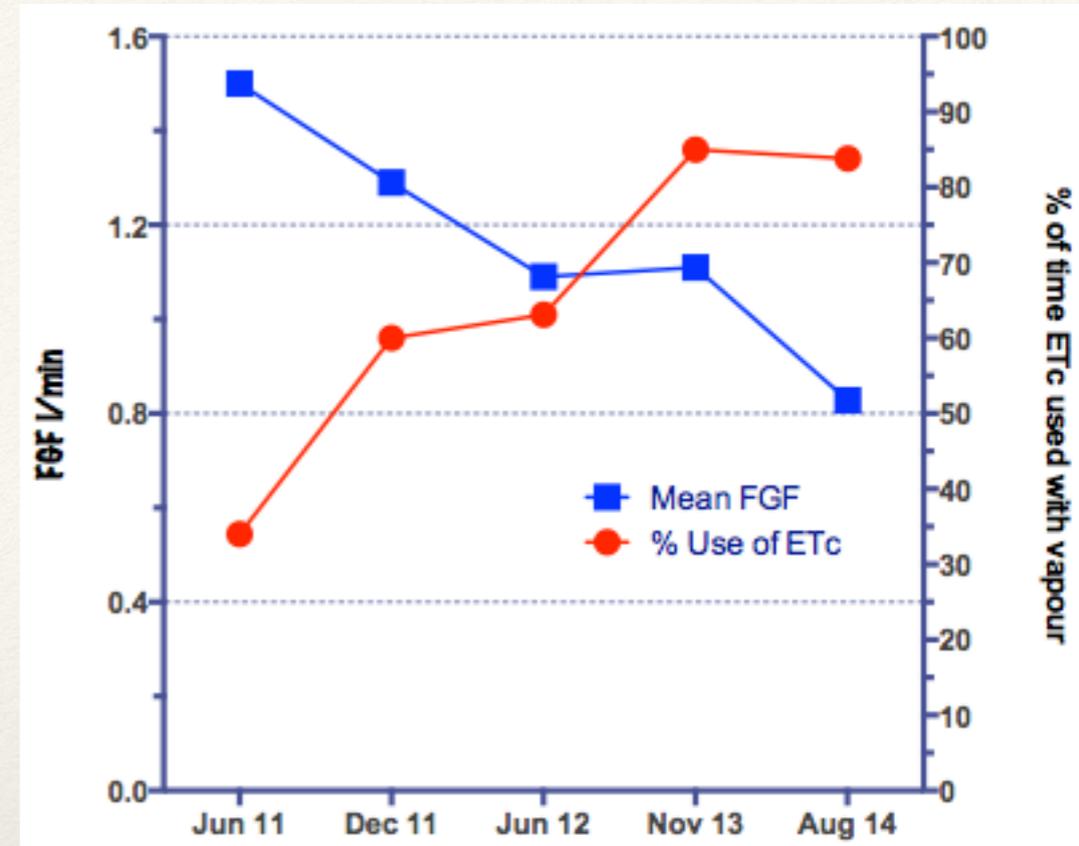
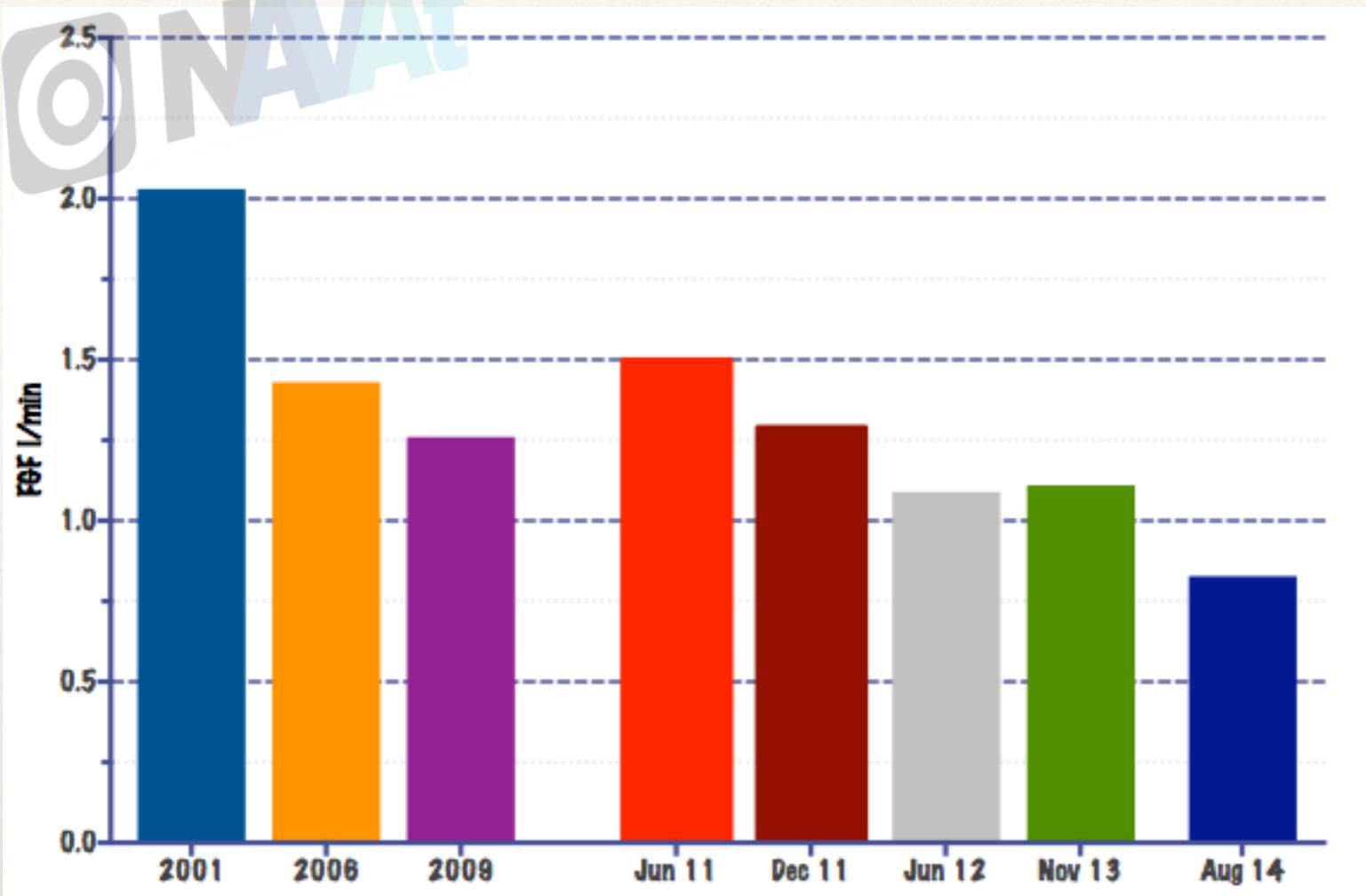
Umberto Lucangelo · Giuliana Garufi · Emanuele Marras · Massimo Ferluga · Federica Turchet · Francesca Bernabè · Lucia Comuzzi · Giorgio Berlot · Walter A. Zin

FGc: 137 adjustments of agent & 107 of O<sub>2</sub>

ETc: no adjustments







- ❖ Average FGF now 832ml/hr - includes induction!
- ❖ Saving compared to 2009 (ADU) > €50,000 pa
- ❖ Aisys in manual mode less efficient than ADU?
  - ❖ Interface changes with CS<sup>2</sup>

