

Economics of Anesthetic Agents and Prolonged Extubations

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Economics of Anesthetic Agents (Focus on Prolonged Extubations)

Franklin Dexter, MD PhD FASA



Director, Division of Management Consulting

Professor, Department of Anesthesia

University of Iowa

Franklin-Dexter@UIowa.edu

www.FranklinDexter.net

Economics of Anesthetic Agents and Prolonged Extubations

- Reducing drug wastage is simplest
- Changing practice relies on individual feedback and appropriate case adjustment
- Economics of prolonged extubations
- Translation of time into \$ is sensitive to the percentage of costs that are fixed
- Predictions require simulation analysis
 - Examples from ICU, PACU, and OR
 - Exceptions are changes in type of anesthesia



Financial Disclosure

- I am employed by the University of Iowa, in part, to consult and analyze data for hospitals, anesthesia groups, and companies
- Department of Anesthesia bills for my time, and the income is used to fund our research
 - I receive no funds personally other than my salary and allowable expense reimbursements from the University of Iowa, and have tenure with no incentive program
 - I own no healthcare stocks (other than indirectly through mutual funds)

Financial Disclosure

- Some work presented in this lecture was funded by consulting done by the University of Iowa (i.e., me) for companies (partial list)
 - Aspect Medical Systems
 - Organon
 - Baxter
 - Merck



Economics of Anesthetic Agents and Prolonged Extubations

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Reducing Fresh Gas Flow Rates Is Simple Conceptually

- Providing feedback to anesthesiologists of their overall mean fresh gas flows reduced consumption by 15% and 26%

Lubarsky DA et al. Anesthesiology 1997

Body SC et al. Anesthesiology 1999



Reducing Fresh Gas Flow Rates Is Simple Conceptually

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 - Most of the benefit is from small reductions in flows for the many cases with rates < 3 liters per minute, not from changing the behavior of few providers with very big flows

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Dexter F et al. Anaesth Intensive Care 2011



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- Providing feedback to anesthesiologists of their overall mean fresh gas flows reduced consumption by 15% and 26%
 - Most of the benefit is from small reductions in flows for the many cases with rates < 3 liters per minute, not from changing the behavior of few providers with very big flows
 - Can use automated, real-time recommendations

Lubarsky DA et al. Anesthesiology 1997

Body SC et al. Anesthesiology 1999

Dexter F et al. Anaesth Intensive Care 2011

Luria I et al. Anesth Analg 2013



Reducing Fresh Gas Flow Rates Is Simple Conceptually

- Real-time q 1 minute means multiple criteria

Nair B et al. Anesthesiology 2013

Ramaswamy P et al. JMIR Periop Med 2022



Reducing Fresh Gas Flow Rates Is Simple Conceptually

- Real-time q 1 minute means multiple criteria
 - Fresh gas flow $>$ threshold for ≥ 5 minutes
 - 0.7 liters/minute for sevoflurane
 - Inhalational agent dial concentration > 0
 - Surgical incision timeout completed
 - Dressing on patient not yet happened
 - Best practice advisory snooze max of 10 minutes

Nair B et al. Anesthesiology 2013

Ramaswamy P et al. JMIR Periop Med 2022



Reducing Fresh Gas Flow Rates Is Simple Conceptually

- Consider education on importance of induction, because median 27% of total fresh gas used during the initial high-flow phase

Kennedy RR et al. Anaesthesia 2019



Reducing Fresh Gas Flow Rates Is Simple Conceptually

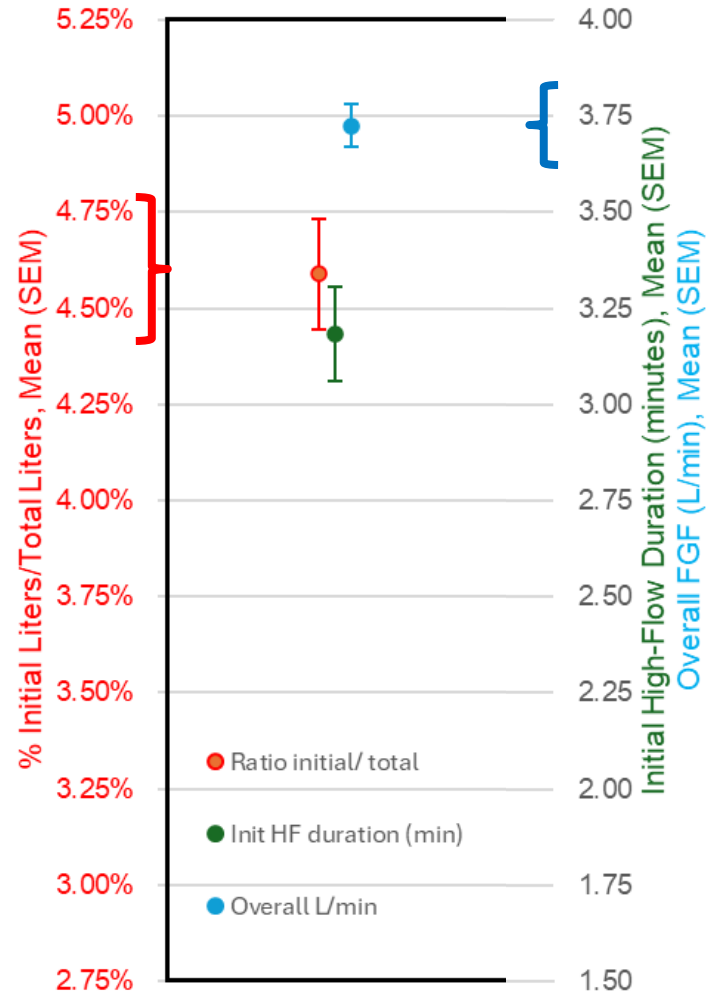
- Consider education on importance of induction, because median 27% of total fresh gas used during the initial high-flow phase once overall fresh gas flow \approx 1.2 liters/minute

Kennedy RR et al. Anaesthesia 2019

Frank Y et al. J Clin Anesth 2025



Reducing Fresh Gas Flow Rates Is Simple Conceptually



Reducing Opened and Unused Drugs Is Simple Conceptually

- FY96, \$9.60 per case (acquisition costs)
 - 28% of total anesthesia drug costs
- FY98, \$13.27 per case
 - 26% of total anesthesia drug costs
- FY00, \$10.86 per case
- FY13, \$ 3.90 per case

Dexter F et al. Anesthesiology 1998

Gillerman RG, Browning RA. Anesth Analg 2000

Weinger MB. J Clin Anesth 2001

Atcheson CLH et al. J Clin Anesth 2016



Reducing Opened and Unused Drugs Is Simple Conceptually

- I recommend starting with this change
 - Easy to quantify
 - Easy to understand that wasting drugs is counter-productive
 - No adverse consequence for patients
 - Reducing fresh gas flows reduces wastage of volatile anesthetics and can help environment



Reducing Opened and Unused Drugs Is Simple Conceptually

- I recommend starting with this change
 - Easy to quantify
 - Easy to understand that wasting drugs is counter-productive
 - No adverse consequence for patients
 - Reducing fresh gas flows reduces wastage of volatile anesthetics and can help environment
- Still, though, will need analysis and software



Example 1 of Reducing Wastage

- Costs and benefits of program to reduce wastage of intravenous drugs using instead commercially prepared syringes is simple to measure
 - Cost of commercial syringe
 - Cost of standard syringe
 - Reduced wastage

Armoiry X et al. Acta Anaesthesiol Scand 2016

Atcheson CLH et al. J Clin Anesth 2016

Jelacic S et al. J Clin Anesth 2017

Barbariol F et al. Anesth Analg 2021



Example 1 of Reducing Wastage

- Which of the following provides the cheapest total cost?
 - Ephedrine 30 mg drawn by anesthesiologist
 - Ephedrine 30 mg obtained commercially
 - No way to know without measuring wastage across multiple hospitals and doing the inventory-control mathematics



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 - Ephedrine 30 mg obtained commercially
 - No way to know without measuring wastage across multiple hospitals and doing the inventory-control mathematics
- Let the pharmacy decision-analyst with software figure it out



Example 2 of Reducing Wastage

- Which of the following provides the cheapest total cost for maintenance?
 - Desflurane with 4.0 liter fresh gas flow
 - Desflurane with 3.0 liter fresh gas flow
 - Desflurane with 2.0 liter fresh gas flow
 - Desflurane with 1.0 liter fresh gas flow



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 - Desflurane with 4.0 liter fresh gas flow
 - Desflurane with 3.0 liter fresh gas flow
 - Desflurane with 2.0 liter fresh gas flow
 - Desflurane with 1.0 liter fresh gas flow
- It really is that simple conceptually
(plus some anesthesia machines have automated control of low-flow delivery)



Economics of Anesthetic Agents and Prolonged Extubations

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- Changing practice relies on individual feedback and appropriate case adjustment
- Economics of prolonged extubations
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 - Examples from ICU, PACU, and OR
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Education Alone Does Not Influence Anesthesia Providers

- Poor cost consciousness of anesthesia providers, particularly for expensive drugs

Schlunzen L et al. Acta Anaesthesiol Scand 1999

Wax DB et al. J Clin Anesth 2009



Education Alone Does Not Influence Anesthesia Providers

- Poor cost consciousness of anesthesia providers, particularly for expensive drugs
- Price stickers and education significantly enhance cost-consciousness

Schlunzen L et al. Acta Anaesthesiol Scand 1999

Wax DB et al. J Clin Anesth 2009

Snyder-Ramos SA et al. Der Anaesthesist 2003



Education Alone Does Not Influence Anesthesia Providers

- Poor cost consciousness of anesthesia providers, particularly for expensive drugs
- Price stickers and education significantly enhance cost-consciousness
- However, that does not change drug usage for equivalent drugs

Schlunzen L et al. Acta Anaesthesiol Scand 1999

Wax DB et al. J Clin Anesth 2009

Snyder-Ramos SA et al. Der Anaesthesist 2003

Horrow JC, Rosenberg H. Can J Anaesth 1994

Provider-Specific Feedback Needs to be Patient Specific

- Determining appropriate patients for anti-emetics relies on logistic regression
 - Female gender
 - Prior history of PONV or motion sickness
 - Nonsmoking
 - Postoperative opioids

Junger A et al. Anesth Analg 2001

Apfel CC et al. Anesthesiology 1999



Provider-Specific Feedback Needs to be Timely



Provider-Specific Feedback Needs to be Timely

- Risk-adjusted outcome feedback increases percentage of patients receiving protocol-driven nausea/vomiting therapy
 - Every 1 month: absolute increase 29%
 - Every 3 months: absolute increase 12%

Overdyk FJ et al. J Clin Anesth 1999

Cohen MM et al. Anesthesiology 1996



Provider-Specific Feedback Needs to be Timely

- Risk-adjusted outcome feedback increases percentage of outpatients bypassing the phase I post-anesthesia care unit
 - Every week: absolute increase 43%
 - Every day: absolute increase 83%

Apfelbaum JL et al. Anesthesiology 2002

Duncan PG et al. Can J Anaesth 2001



Provider-Specific Feedback Needs to be Timely

- Provide immediate feedback when using drug that is not part of protocol for the patient
 - Reduced intravenous anesthetic costs 51%
 - Reduced neuromuscular blocker costs 47%

Lubarsky DA et al. Anesthesiology 1997

Freund PR et al. Anesthesiology 1997



Provider-Specific Feedback Needs to be Timely

- Provide immediate feedback when using drug that is not part of protocol for the patient
 - Reduced intravenous anesthetic costs 51%
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- Can provide using either drug dispensing system or using anesthesia information management system (AIMS)

Epstein RH et al. Anesth Analg 2016 (× 2)



Provider-Specific Feedback Needs to be Timely

- Provide immediate feedback when using drug that is not part of protocol for the patient
 - Reduced intravenous anesthetic costs 51%
 - Reduced neuromuscular blocker costs 47%
- Can provide using either drug dispensing system or using anesthesia information management system (AIMS)
- Advantages to delivering by e-mail include appropriate lack of regulatory requirements and ease of maintenance



Provider-Specific Feedback on Costs Need to be Adjusted

- American Society of Anesthesiologists' Relative Value Guide (ASA RVG) were known for every case that was billed (i.e., for every case)
 - Case duration: use ASA RVG time units
 - Type of procedure: use ASA RVG base units
- Explained 54% of variation in costs
 - Corrected for variation in anesthetic drug costs among sub-specialties

Dexter F et al. Anesthesiology 1998



Provider-Specific Feedback Can Also Include Time

- Monitor the 15% of AIMS' cases with prolonged extubation times (≥ 15 min)
 - Direct cost of the time focus of rest of talk
 - Intangible cost of the time shown by these cases' having mean 4.9 min longer times from out of OR to start of surgery of surgeon's next case (95% CI 2.7 min to 7.1 min, $P < 0.0001$)

Dexter F et al. Anesth Analg 2010

Masursky D et al. Anesth Analg 2012

Dexter F, Hindman BJ. Anesth Analg 2024



Provider-Specific Feedback Can Also Include Time

- Incidence of prolonged extubation times is composite end point for reductions in both:
 - Average (mean)
 - Variability (standard deviation)

Dexter F et al. Anesth Analg 2010

Dexter F, Hindman BJ. Anesth Analg 2024

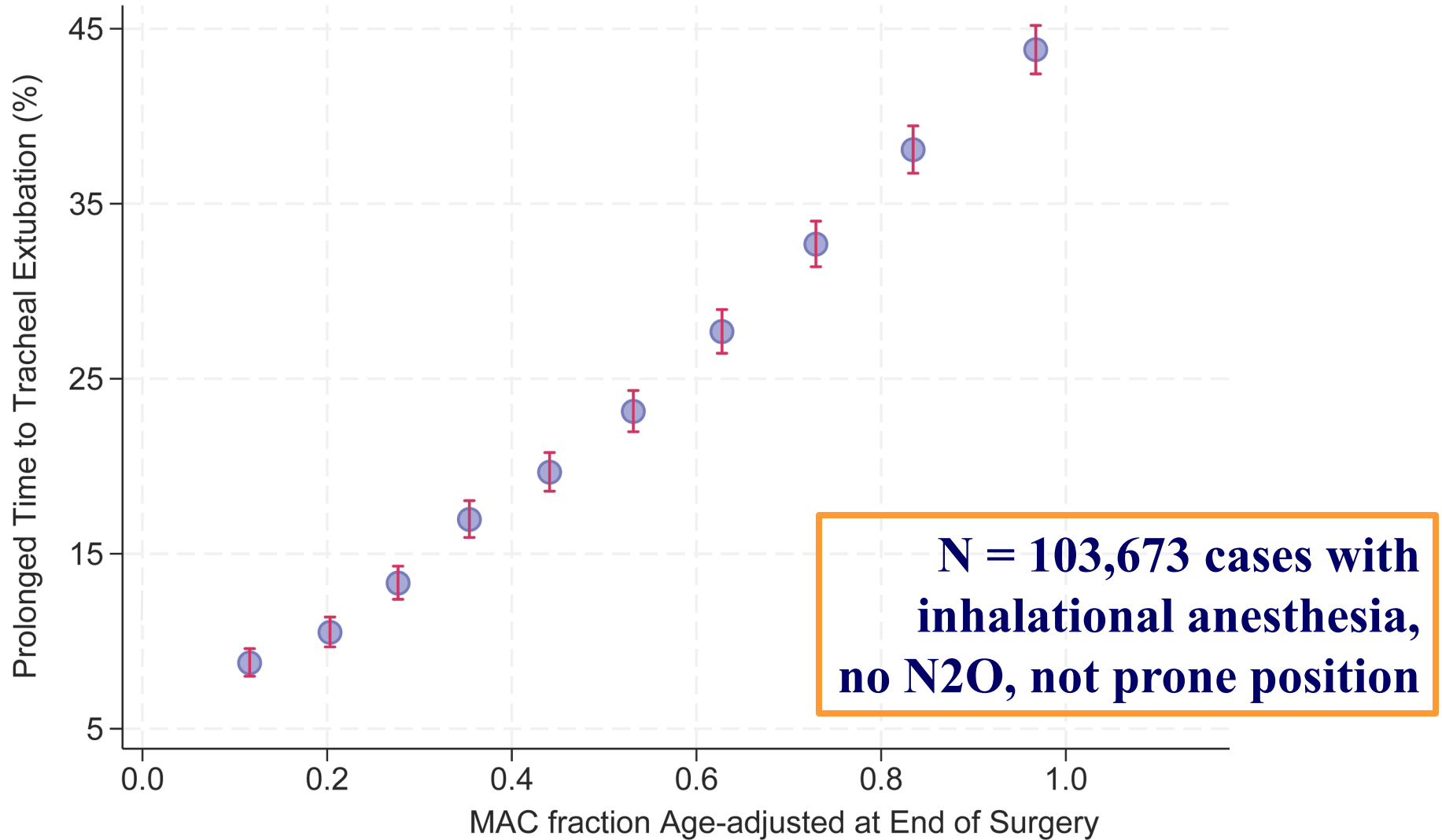


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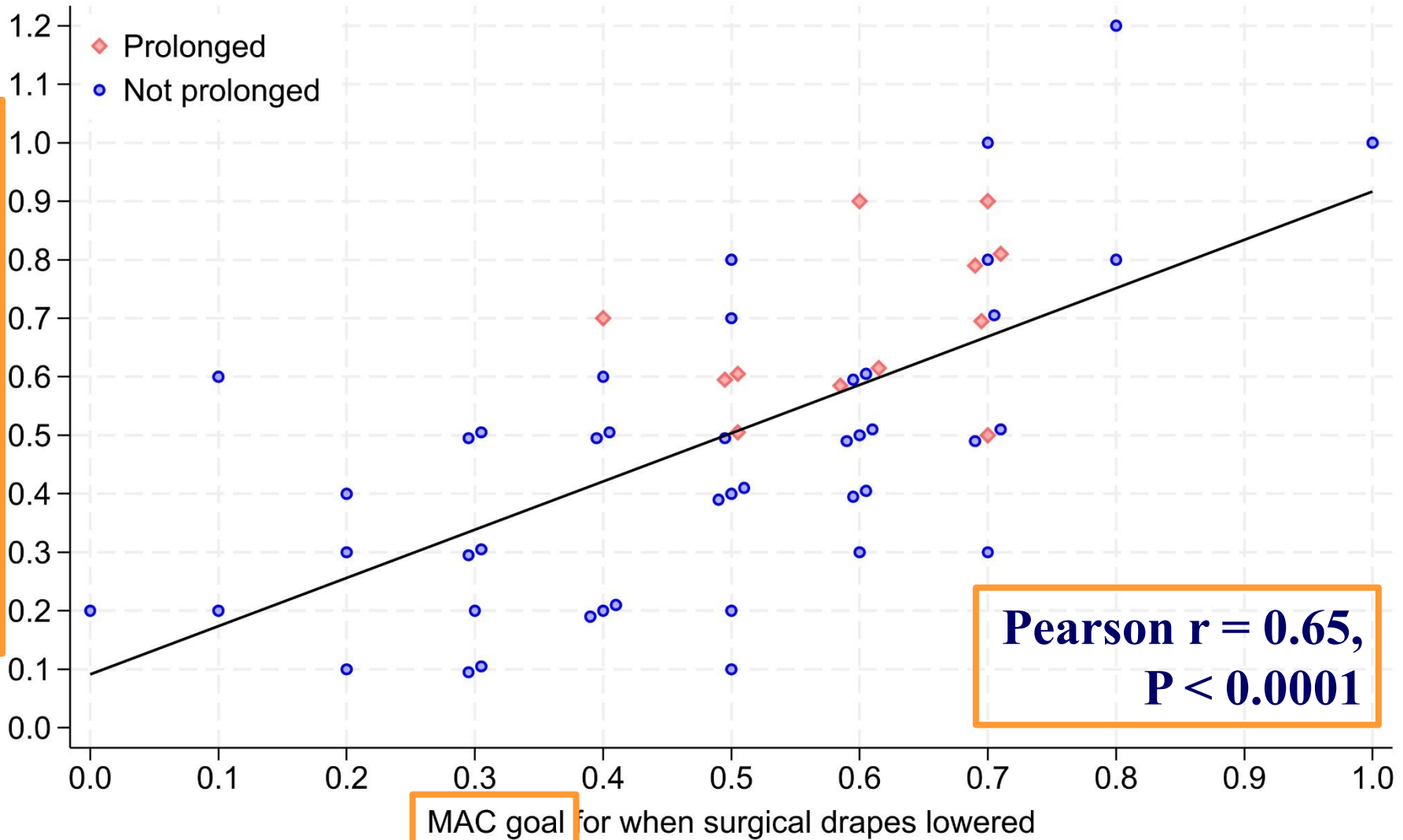
- Incidence of prolonged extubation times is composite end point for reductions in both:
 - Average (mean)
 - Variability (standard deviation)
- Mostly variability
 - Prolonged 39% University of Iowa (N=785) vs. 6% Kameda Medical Center (N=685)
 - Means 10 vs. 9 minutes ($P = 0.68$)
 - Standard deviations 40 vs. 4 min ($P < 0.0001$)



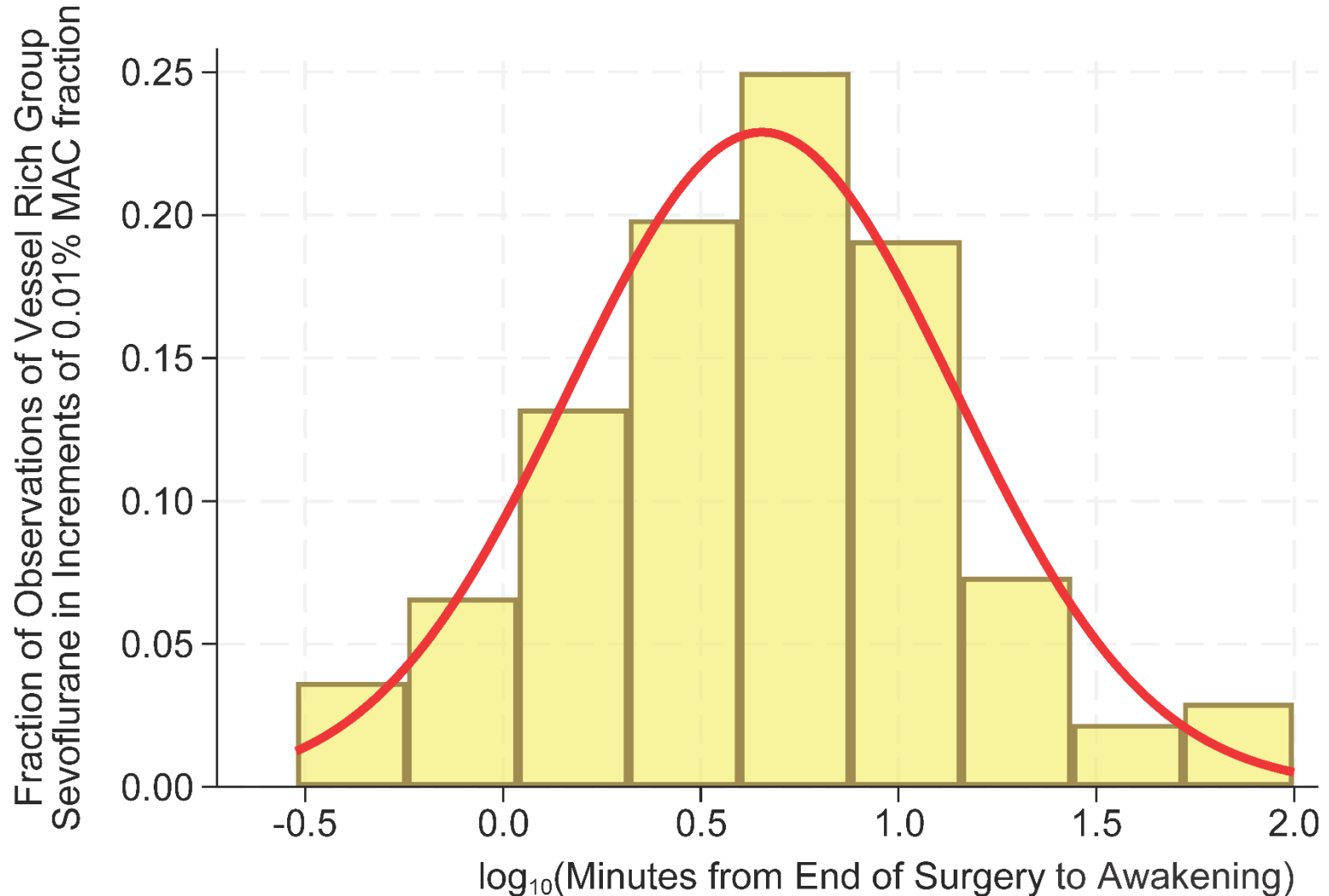
Prolonged Extubations are Often Preventable



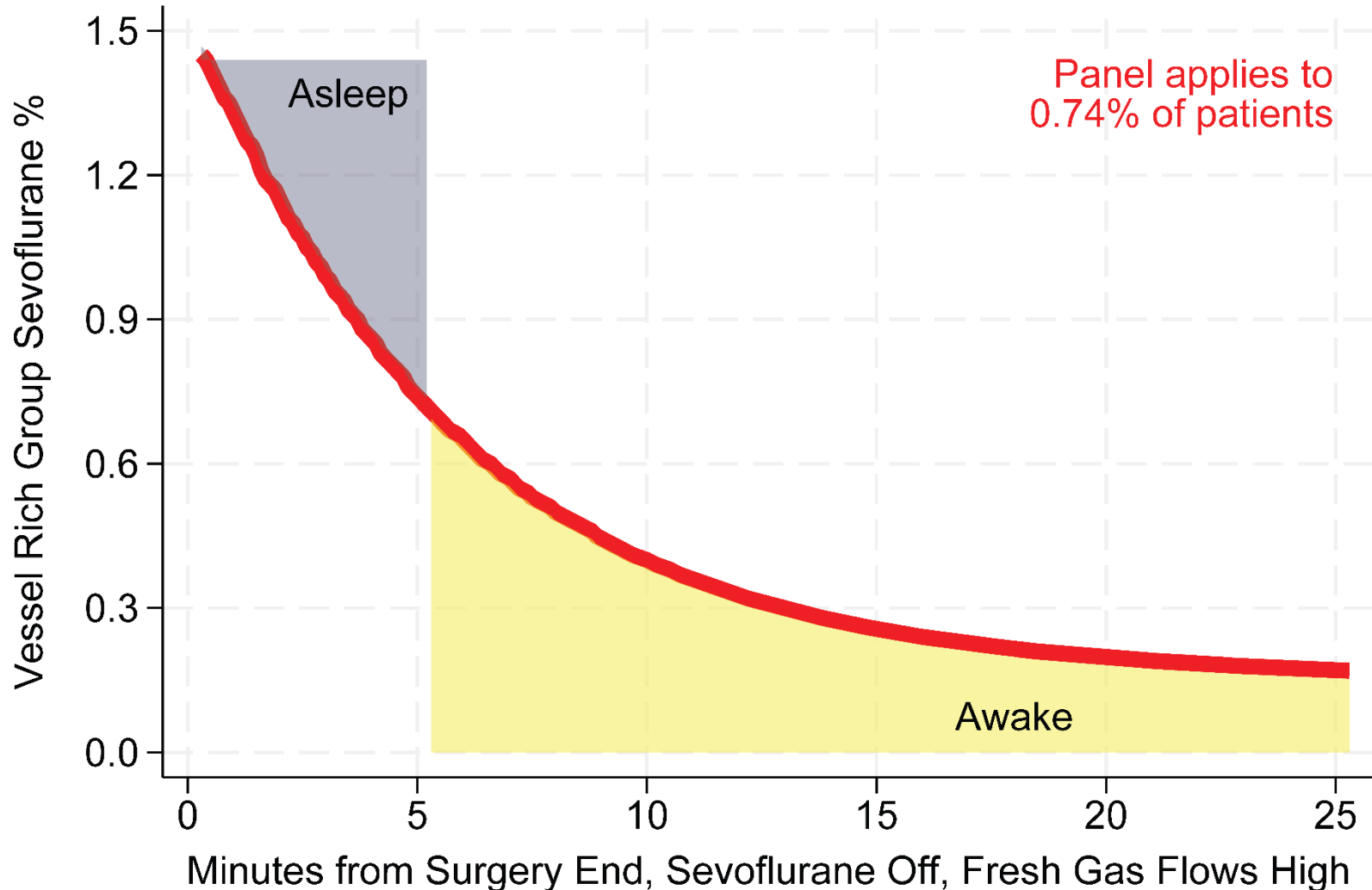
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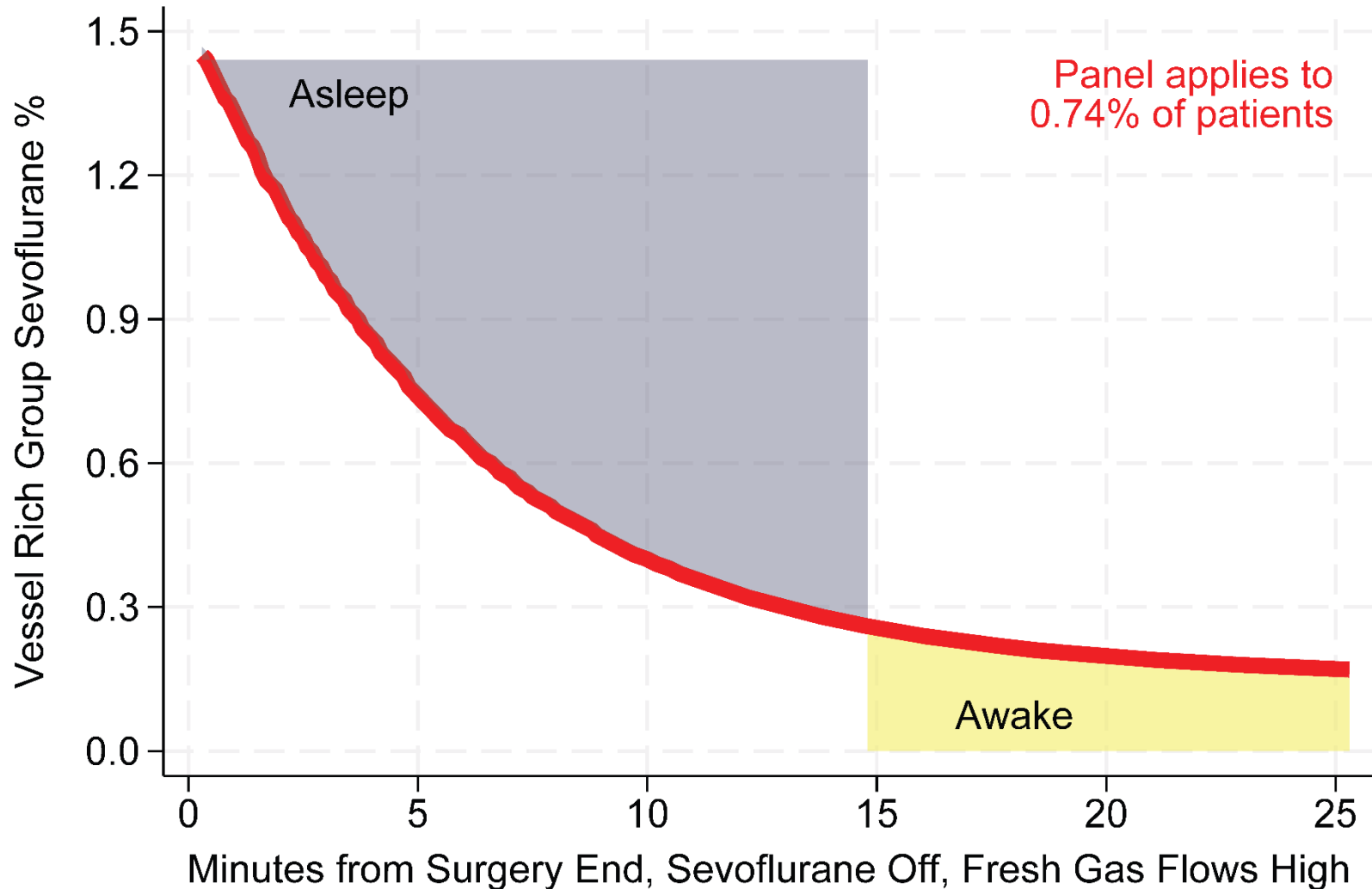
Conceptualizing and Controlling MAC Fraction at End of Surgery



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Conceptualizing and Controlling MAC Fraction at End of Surgery

- Why MAC fraction of 0.5%, age adjusted?
 - Less than 0.5% was threshold for intraoperative alert in Michigan Awareness Control Study, same rate as using BIS monitor
- Why rely too on MAC-awake, sevoflurane 0.62% (before adjusting for age)?
 - Higher than MAC-amnesia

Mashour GA et al. Anesthesiology 2012

Aranake A et al. Anaesthesia 2013

Egan TD et al. Br J Anaesth 2023



Conceptualizing and Controlling MAC Fraction at End of Surgery

- Start of closure, set vaporizer to MAC-awake and fresh gas flow to 8 liters per minute
- 2 minutes later
 - End-tidal agent MAC fraction 0.5%
 - Vaporizer to maintain that 0.5% MAC fraction, sevoflurane 0.68% before age adjustment
 - Fresh gas flow back down to 1 liter per minute
- Maintain end-tidal MAC fraction 0.5% to end



Conceptualizing and Controlling MAC Fraction at End of Surgery

- 2 minutes < mean (standard deviation) of 5.22 (3.68) minutes, the 5th percentiles of times for surgical closure for each of N=244 surgical procedures each with ≥ 29 cases
- If instead vaporizer down to MAC awake while maintaining 1 liter per minute fresh gas flow, 28 minutes to reach MAC fraction of 0.5%
 - Longer than the 5th percentile of times for surgical closure among all 244 procedures



Prolonged Extubations are Often Preventable

- Can also reduce the incidence of prolonged extubation by using desflurane
 - Reduces incidence 65% versus sevoflurane
 - Reduces incidence 78% versus isoflurane

Dexter F et al. Anesth Analg 2010

Agoliati A et al. Anesth Analg 2010

Dexter F, Hindman BJ. J Clin Anesth 2023



Value of 75% Reduction Differs Depending on Incidence

- Ambulatory surgery center OR
 - 1000 general anesthetics per year × 5% rate of prolonged extubation times = 1 event per week
 - 75% reduction results in 1 event per month
- Hospital OR
 - 750 general anesthetics per year × 25% rate of prolonged extubation times = 4 events per week
 - 75% reduction results in < 1 event per week

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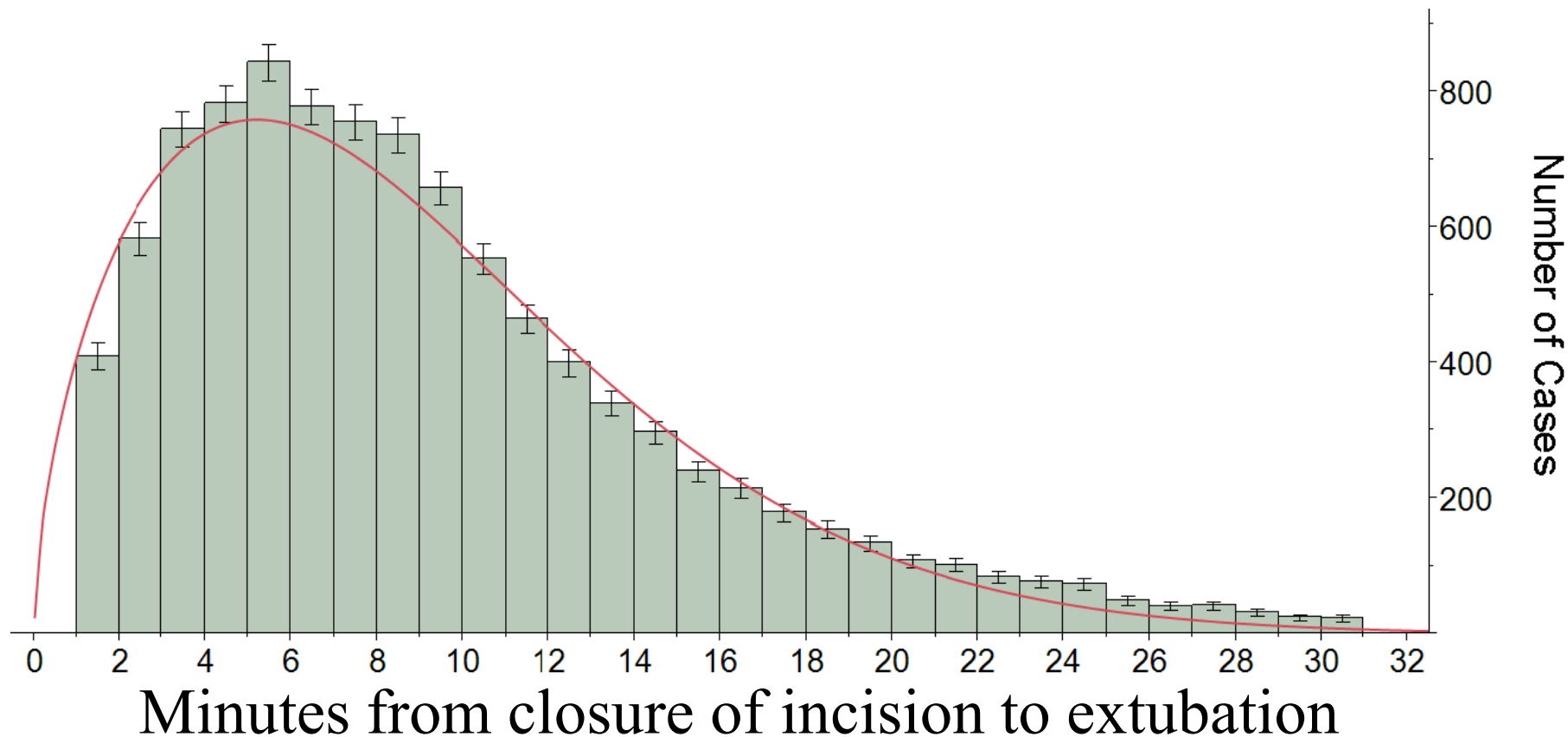
Matters That Drugs Influence Anesthetic Times

Get your anesthesia
performance on the
fast track.

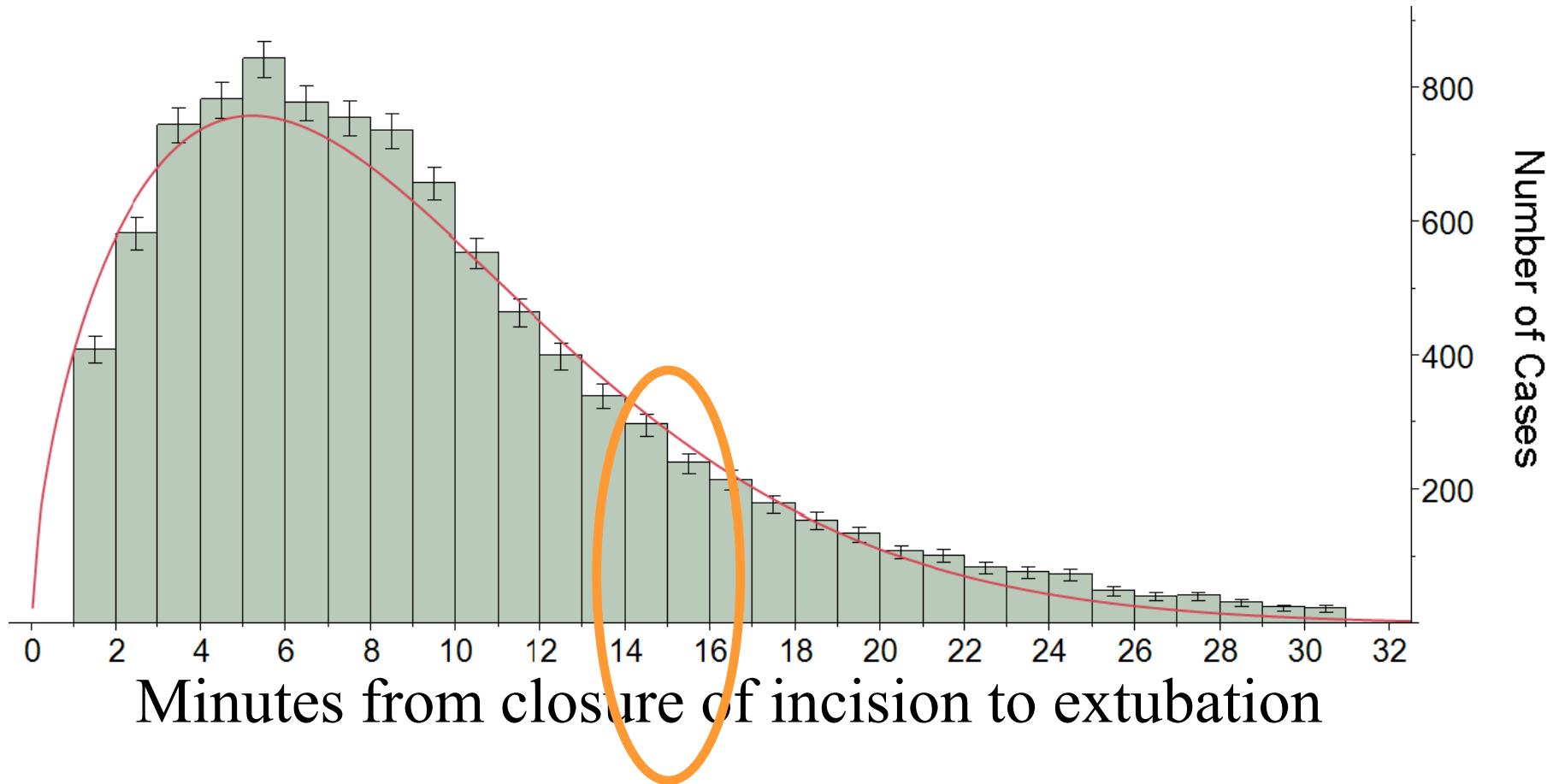
 **Suprane**[®]
desflurane, USP
THE FAST TRACK ANESTHETIC[™]



Matters That Drugs Influence Anesthetic Times



Matters That Drugs Influence Anesthetic Times



Matters That Drugs Influence Anesthetic Times

- Prolonged extubations cause increase in times from end of surgery to OR exit?
 - No, not significantly, other concurrent processes influence time of OR exit
 - Yes, significantly, but just 1 to 2 minutes
 - Yes, significantly, on average \cong 5 minutes
 - Yes, significantly, on average $>$ 10 minutes

Dexter F, Epstein RH. Anesth Analg 2013

Dexter F, Hindman BJ. Anesth Analg 2024



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Dexter F, Hindman BJ. Anesth Analg 2024



Matters That Drugs Influence Anesthetic Times

- Prolonged extubations cause increase in times from end of surgery to OR exit
 - Mean 13.0 ± 0.1 minutes (SE) when stratified by duration of surgery and prone or not
 - Longer than 10 minutes, $P < 0.0001$
 - Absolute % increase in risk of case taking longer than scheduled is $11.0\% \pm 0.5\%$

Dexter F, Epstein RH. Anesth Analg 2013

Dexter F et al. BMC Anesthesiology 2025



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- Monitoring prolonged extubations is valid

Masursky D et al. Anesth Analg 2012

Bayman EO et al. Anesthesiology 2016



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 - Longer than 10 minutes, $P < 0.0001$
 - Absolute % increase in risk of case taking longer than scheduled is $11.0\% \pm 0.5\%$
- Monitoring prolonged extubations is valid
 - Unlike time from end of surgery to OR exit, since increased by factors unrelated to anesthetic such as the PACU being full

Matters That Drugs Influence Anesthetic Times

- Drugs with a higher acquisition costs can truly be cheaper by reducing time

Tyler DC, Orr RJ. Am J Anesthesiol 1999



Matters That Drugs Influence Anesthetic Times

- Drugs with a higher acquisition costs can truly be cheaper by reducing time
- Anesthesiologists give poor rating to recovery from anesthesia when prolonged extubation

Tyler DC, Orr RJ. Am J Anesthesiol 1999

Apfelbaum JL et al. Anesth Analg 1993



Matters That Drugs Influence Anesthetic Times

- Drugs with a higher acquisition costs can truly be cheaper by reducing time
- Anesthesiologists give poor rating to recovery from anesthesia when prolonged extubation
- Anesthesiologists perceive strong production pressure to work quickly

Tyler DC, Orr RJ. Am J Anesthesiol 1999

Apfelbaum JL et al. Anesth Analg 1993

Gaba DM et al. Anesthesiology 1994

Chai JX, Chong SY. Singapore

Med J 2018

Matters That Drugs Influence Anesthetic Times

- Drugs with a higher acquisition costs can truly be cheaper by reducing time
- Anesthesiologists give poor rating to recovery from anesthesia when prolonged extubation
- Anesthesiologists perceive strong production pressure to work quickly

➤ Cognitive bias (i.e., immutable to education)

Tyler DC, Orr RJ. Am J Anesthesiol 1999

Apfelbaum JL et al. Anesth Analg 1993

Gaba DM et al. Anesthesiology 1994

Dexter F et al. Anesth Analg 2007

Ledolter J et al. Anesth Analg 2010

Chai JX, Chong SY. Singapore

Med J 2018

Wang J et al. Anesth Analg 2013

Matters That Drugs Influence Anesthetic Times

- Surgeons scored importance of 25 attributes of anesthesiologists, using scale from 0 "no importance" to 4 "a factor that would make me switch groups/ hospitals"
- For example, as expected, mean score 4.0 for "ability to calmly manage a crisis."

Vitez TS, Macario A. J Clin Anesth 1998



Matters That Drugs Influence Anesthetic Times

- Surgeons scored importance of 25 attributes of anesthesiologists, using scale from 0 "no importance" to 4 "a factor that would make me switch groups/ hospitals"
- For example, as expected, mean score 4.0 for "ability to calmly manage a crisis."
- Mean score 3.9 for "patient quick to awaken."

Vitez TS, Macario A. J Clin Anesth 1998



Measuring Reductions in Time is Straight-Forward

- Results well summarized by meta-analyses
- Example of mean time to extubation
 - Desflurane 25% quicker than sevoflurane
 - 95% confidence interval 17% to 32%
 - Typical corresponding value is 2.5 min

Dexter F et al. Anesth Analg 2010



Small Time Savings per Case Do Not Simply Add Up

- A hospital estimates its variable costs of OR time to be \$20 per minute
 - From cost accounting system
- Desflurane reduces time to following commands by an average of 2.5 minutes
- Savings = \$50 per case
 - $\$50 = \$20 \text{ per min} \times 2.5 \text{ min per case}$

Dexter F et al. Anesthesiology 2002



Small Time Savings per Case Do Not Simply Add Up

- A hospital estimates its variable costs of OR time to be \$20 per minute
 - From cost accounting system
- Desflurane reduces time to following commands by an average of 2.5 minutes
- Savings = \$50 per case
 - $\$50 = \$20 \text{ per min} \times 2.5 \text{ min per case}$
 - Absurd! Use of desflurane did not save \$50



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Operating Room Labor is a Step Cost

- Cost accounting system models the variable cost of:

OR time \cong (cost of the patient care labor) \div
(direct patient care time during one quarter)



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(direct patient care time during one quarter)
- Assumption is reasonable for an OR allocation analysis that may result in closing an OR

Macario A, Dexter F. AORN J 2000



Operating Room Labor is a Step Cost

- Cost accounting system models the variable cost of:
OR time \cong (cost of the patient care labor) \div
(direct patient care time during one quarter)
- Assumption is reasonable for an OR allocation analysis that may result in closing an OR
- Assumption is not reasonable when considering impact of an anesthetic agent



Operating Room Labor is a Step Cost

- Fixed costs
 - Do not change relative to volume of activity
 - Capital equipment and snow removal
- Variable costs
 - Change relative to volume of activity
 - Vials of propofol
- Step costs
 - Staffing is fixed over narrow ranges of volume of activity, but beyond that must increase



Operating Room Labor is a Step Cost

- Cost accounting system assumes that staff time is a variable cost



Operating Room Labor is a Step Cost

- Cost accounting system assumes that staff time is a variable cost
- If close an OR, then will have fewer full-time staff, and so the assumption is reasonable over a time course of several months



Operating Room Labor is a Step Cost

- Cost accounting system assumes that staff time is a variable cost
- If close an OR, then will have fewer full-time staff, and so the assumption is reasonable over a time course of several months
- If one anesthesiologist decides today to do something different and reduces OR time, then assumption may not be appropriate



Example – Change in Practice Today by One Anesthesiologist

- 20 anesthesiologist MD group practices at a hospital's main OR & ambulatory surgery center
- Every Monday, ORs start 1-hr late for nursing training and the anesthesia group's meeting
- This Monday, hospital manager provides the anesthesiologists with data showing need to reduce drug costs, PACU costs, and OR costs
- Anesthesia group agrees to set up a committee to collaborate with hospital on future changes



Example – Change in Practice Today by One Anesthesiologist

- One of the anesthesiologists, though, wants to affect change immediately
- She is doing five short cases today
- To reduce drug costs, she draws up drugs into small syringes, and reduces wastage
- To reduce PACU costs, she uses BiS and runs a patient light, bypassing phase I PACU
- To reduce OR costs, she administers a spinal instead of an epidural anesthetic, cutting OR time by around 12 minutes



Example – Change in Practice Today by One Anesthesiologist

- For which interventions did she really cut costs?
 - To reduce drug costs, she draws up drugs into small syringes, and reduces wastage
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***Long-Term* Change in Practice by Many Anesthesiologists**

- Which interventions really do cut costs?
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 - All 3 of them



***Long-Term* Change in Practice by Many Anesthesiologists**

- Which interventions really do cut costs?
 - To reduce drug costs, they draw up drugs into small syringes, and reduce wastage
 - To reduce PACU costs, they use BiS and run their patients light, bypassing phase I PACU
 - To reduce OR costs, they administer spinals instead of epidural anesthetics, cutting OR times by around 12 minutes
 - All 3 of them



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Example 1 of Cardiac Surgery Scenario

- Dr. Jones is a cardiac anesthesiologist
- Off-pump CPB case with extubation in OR
 - Remifentanyl anesthetic
- Patient leaves ICU early that evening
- Have ICU nursing costs been reduced?
 - Yes, because every hour of ICU time costs hundreds of dollars
 - No, generally not, because ICU nurses are scheduled a month or so ahead of time



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 - Have ICU nursing costs been reduced?
 - Yes, because every hour of ICU time costs hundreds of dollars
- No, generally not, because ICU nurses are scheduled a month or so ahead of time



Example 2 of Cardiac Surgery Scenario

- All cardiac anesthesiologists at the hospital
- After off-pump CPB, 90% of patients are extubated in the OR after surgery
- All patients leave ICU in 6 hours
- ICU nursing costs may be reduced
 - Depends on characteristics of the ICU

Straka Z Ann Thorac Surg 2002



Purpose of the Simulation (Economic) Analysis

- Determine whether a reduction in staffing costs can likely be achieved at specific facility
- Facility specific answer depends on ...
 - Whether costs fixed, varies among facilities
 - Reduction in costs if they are not fixed
$$\text{Not (mean minutes saved)} \times \frac{(\text{total costs})}{(\text{total facility minutes})}$$
 - Cost of drug (or device) at the facility

Healy WL et al. J Arthroplasty 1998

Taheri PA et al. J Am Coll Surg 2000



Economics of Anesthetic Agents and Prolonged Extubations

- Reducing drug wastage is simplest
- Changing practice relies on individual feedback and appropriate case adjustment
- Economics of prolonged extubations
- Translation of time into \$ is sensitive to the percentage of costs that are fixed
- Predictions require simulation analysis
 - Examples from ***ICU***, PACU, and OR
 - Exceptions are changes in type of anesthesia



Early Tracheal Extubation of Cardiac Surgery Patients

- Early tracheal extubation, achieved with propofol, reduced mean time to extubation from 19 hours to 4 hours, resulting in a reduction in mean ICU LOS of 5.1 hour
- Mean reduction in costs of part-time ICU nurses was \$1,012 per patient

Cheng DCH et al. Anesthesiology 1996



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Sensitivity of Early Extubation Results to ICU Characteristics

- Cost reduction sensitive to patient flow from scheduling to OR to ICU to hospital ward to long-term care and/or home
 - Specifically, reduction in ICU nursing costs sensitive to number of elective CABG cases performed each year at the hospital and the method of compensating ICU nurses

Dexter F et al. J Clin Anesth 1998



Sensitivity of Early Extubation Results to ICU Characteristics

- 830 per year \cong 3-4 elective CABG per day
 - 5 hr reduction in ICU time reliably represents 1 less ICU nurse each day
 - Savings are particularly reasonable, because many part-time nurses



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 - 5 hr reduction in ICU time reliably represents 1 less ICU nurse each day
 - Savings are particularly reasonable, because many part-time nurses
- Median elective CABG per day at US hospitals
 - 1 per day with few part-time ICU nurses
 - Reducing ICU time for 0-1 patients per day for 5 hours unlikely to reduce costs



Two Broad Messages From That ICU Example

- Reductions in time from changing anesthetic drugs *can*, not do, reduce costs
- There needs to be, on that day of the week, a consistently large number of patients who receive the intervention
 - When staff provide care to many patients, only some of whom receive an intervention, the intervention is less likely to reduce costs



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Methodologies to Simulate Effect of Drugs on PACU Costs

- Dexter F, Tinker JH. Analysis of strategies to decrease post anesthesia care unit costs. *Anesthesiology* 1995
- Dexter F et al. Computer simulation to determine how rapid anesthetic recovery protocols to decrease the time for emergence or increase the phase I post anesthesia care unit bypass rate affect staffing of an ambulatory surgery center. *Anesth Analg* 1999
- Dexter F et al. Statistical analysis by Monte-Carlo simulation of the impact of administrative and medical delays in discharge from the post-anesthesia care unit on total patient care hours. *Anesth Analg* 2001



Important Point is Simply that the Methodologies Exist

- Result, of this type of science, is ...
 - Not an answer to the question: “Does X drug reduce costs”
 - Development and validation of methods to be used with each facility’s own data
- Second of the papers includes Tables that are sufficient for a facility to screen an intervention to decide whether an analysis of its own data is worthwhile



Methodologies to Simulate Effect of Drugs on PACU Costs

- Future slides will focus on some broad, bottom-line, principles from the simulations



Impact of Nausea and Vomiting

- Observations from the University of Iowa's Ambulatory Surgery Center in 1993
 - 69% of patients received general anesthesia
 - 8% of patients having general anesthesia suffered nausea and vomiting in the PACU
 - Among patients undergoing general anesthesia, nausea or vomiting increased the mean length of stay by 63%

Dexter F, Tinker JH. Anesthesiology 1995



Impact of Nausea and Vomiting

- Can use these numbers to estimate the decrease in total length of stay that is achievable by reducing nausea and vomiting
 - 69% general
 - 8% of general patients with N & V
 - If N & V, 63% increase in PACU LOS



Impact of Nausea and Vomiting

- Simple estimation

- Staffing impact = (Incidence) × (Impact)
- Eliminating nausea and vomiting would decrease total length of stay by 3.4%

$$3.4\% = (69\% \text{ receiving general} \times 8\% \text{ of those receiving general having nausea and/or vomiting}) \times (63\% \text{ prolongation of length of stay})$$



Impact of Nausea and Vomiting

- An argument in favor of the aggressive prophylactic treatment of nausea and vomiting is that patients with nausea and vomiting have long PACU stays
- However, ...



Impact of Nausea and Vomiting

- An argument in favor of the aggressive prophylactic treatment of nausea and vomiting is that patients with nausea and vomiting have long PACU stays
- PACU patients tend to be in one big room



Impact of Nausea and Vomiting

- An argument in favor of the aggressive prophylactic treatment of nausea and vomiting is that patients with nausea and vomiting have long PACU stays
- PACU patients tend to be in one big room
 - Even if there is a subgroup of patients with a high incidence of nausea and vomiting, staffing impact is based on incidence and impact of all patients



Impact of Eliminating Adverse Events Observed in PACU

- Eliminate all adverse events in the PACU including all nausea and vomiting
 - Reducing incidence in half would result in 4.8% reduction in mean nursing workload
 - Elimination of all adverse events would reduce overall mean length of stay by 6.7% among ambulatory surgery patients in 1999

Cohen MM et al. Anesthesiology 1999

Chung F, Mezei G. Anesth Analg 1999



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 - Elimination of all adverse events would reduce overall mean length of stay by 6.7% among ambulatory surgery patients in 1999
 - Reduce by 1.8% all types of patients in 2018

Cohen MM et al. Anesthesiology 1999

Chung F, Mezei G. Anesth Analg 1999

Liu S et al. J PeriAnesth Nurs 2020



Examples So Far Have Shown Four Broad Principles

- Reductions in time from anesthetic drugs
 - *Can* reduce costs, not do reduce costs
- Cost reductions, achieved from time reductions, are sensitive to characteristics of the facility studied:
 - Method of staff compensation
 - Average numbers of patients receiving care at the facility on that day of the week
 - Percentage of patients who would receive drug and benefit from time reduction

Examples So Far Have Shown Four Broad Principles

- Economics of drug sensitive to context of use
 - Mostly issue of patients not receiving drug
 - Method of staff compensation
 - Average numbers of patients receiving care at the facility on that day of the week
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Examples So Far Have Shown Four Broad Principles

- Economics of drug sensitive to context of use
 - Mostly issue of patients not receiving drug
- As study a drug (or device), also investigate for future potential users what variables should be considered about each facility:
 - Method of staff compensation
 - Average numbers of patients receiving care at the facility on that day of the week
 - Percentage of patients who would receive drug and benefit from time reduction

Economics of Anesthetic Agents and Prolonged Extubations

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Fixed or Variable Cost of OR Time at 6 OR Surgical Suite

- A 6 OR ambulatory surgery center is staffed fully from 7 AM to 5 PM
- Average number of ORs in use, being cleaned, or being setup are as follows:

| | | | |
|------|-----|------|-----|
| 1 PM | 6.0 | 4 PM | 2.8 |
| 2 PM | 5.7 | 5 PM | 0.3 |
| 3 PM | 4.9 | | |



Fixed or Variable Cost of OR Time at 6 OR Surgical Suite

- Ambulatory surgery center has more staffed hours than needed to complete the cases
 - Maybe to encourage increased volume
 - Maybe provides lowest possible costs
 - Maybe a collective bargaining agreement
- Regardless of why the staffing is as it is, reducing OR time will not reduce costs



Fixed or Variable Cost of OR Time at 6 OR Surgical Suite

- Ambulatory surgery center has more staffed hours than needed to complete the cases
 - Maybe to encourage increased volume
 - Maybe provides lowest possible costs
 - Maybe a collective bargaining agreement
- Regardless of why the staffing is as it is, reducing OR time will not reduce costs
- In this example, OR staffing costs are a fixed cost of the number of ORs that are being run



Fixed or Variable Cost of OR Time at 6 OR Surgical Suite

- If the facility were to change staffing to be a mixture of 8 hr and 10 hr ORs,
 - By specialty by day of the week calculated based on maximizing the efficiency of use of OR time
- Then, reducing OR time would substantially reduce costs

More examples

www.FranklinDexter.net/Lectures/TurnoverTime.pdf

Dexter F, Epstein RH. Periop Care Oper Room Manag 2024

Dependency is Very Well Understood – Science is Mature

- Question showing little knowledge: “Does reducing OR time by 7 min save money?”
- Not because science is not well developed, but since conditions differ among facilities
 - Relationship can be predicted with each facility’s own data

McIntosh C et al. Anesth Analg 2006

Epstein RH et al. Can J Anesth 2013

Dexter F, Epstein RH. Periop Care Oper Room Manag 2024

Dependency is Very Well Understood – Science is Mature

- Principle that can be used for purposes of screening to decide whether to apply methods
 - For ORs with < 8 hr of cases, assume OR time is a fixed cost
 - For ORs with > 8 hr of cases, treat each reduction of 1 min OR time as resulting in savings of 1.1 min to 1.2 min of labor time

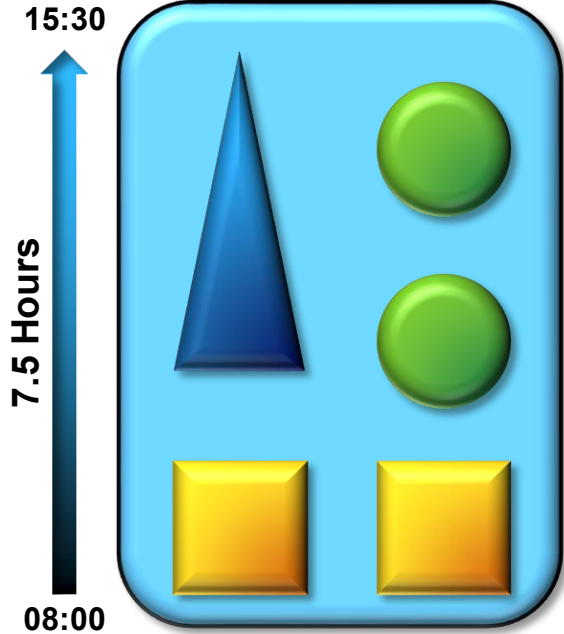
Dexter F et al. Anesth Analg 1999

Dexter F et al. Anesth Analg 2009 & 2010

Epstein RH et al. Can J Anesth 2013

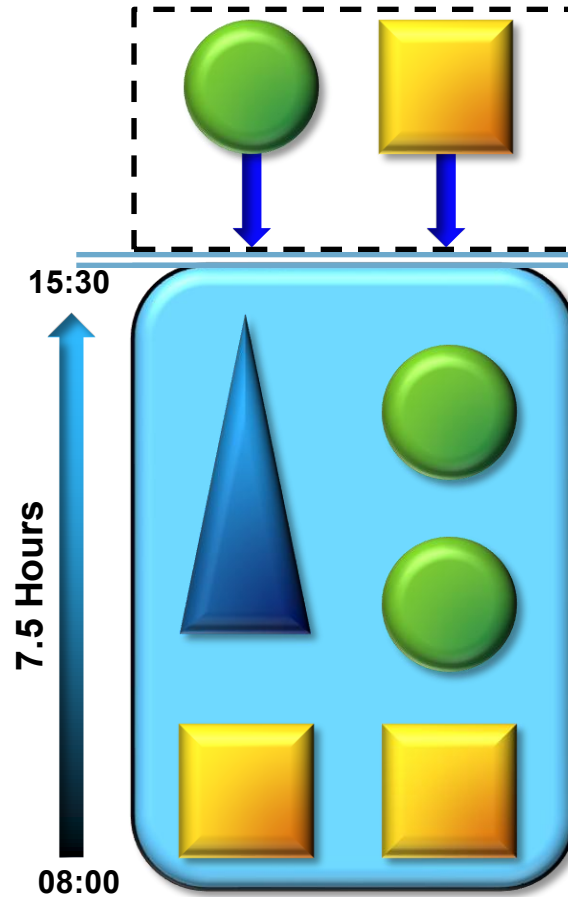
Dexter F, Epstein RH. Periop Care Oper Room Manag 2024

**Regular
OR Schedule**



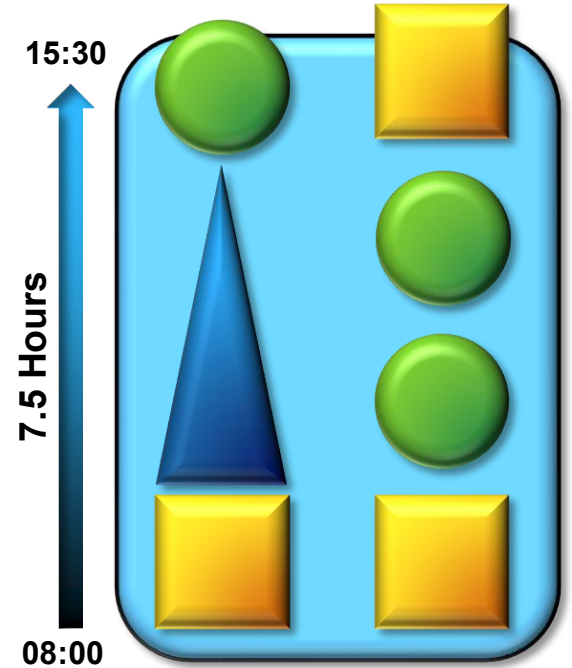
Sevoflurane

**Extended
OR Schedule**



Either

**Regular
OR Schedule**



Desflurane

**Regular
OR Schedule**

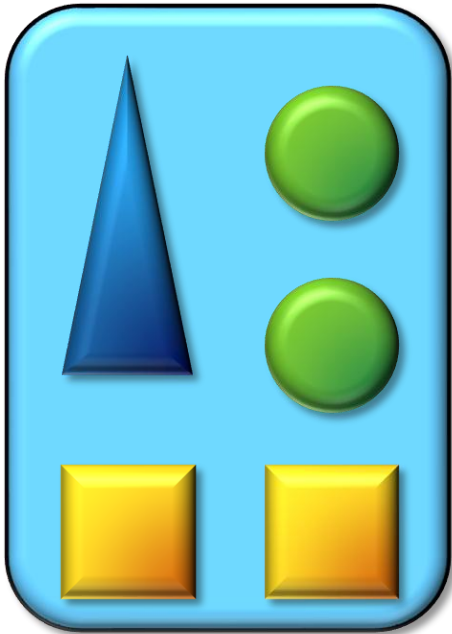
**Extended
OR Schedule**

**Regular
OR Schedule**

15:30

7.5 Hours

08:00

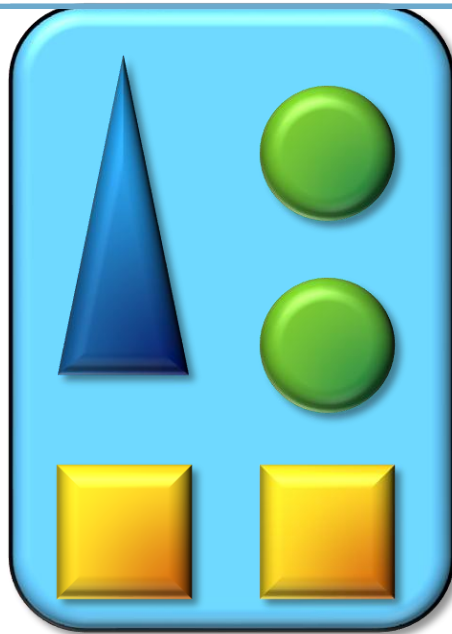


Sevoflurane

15:30

7.5 Hours

08:00

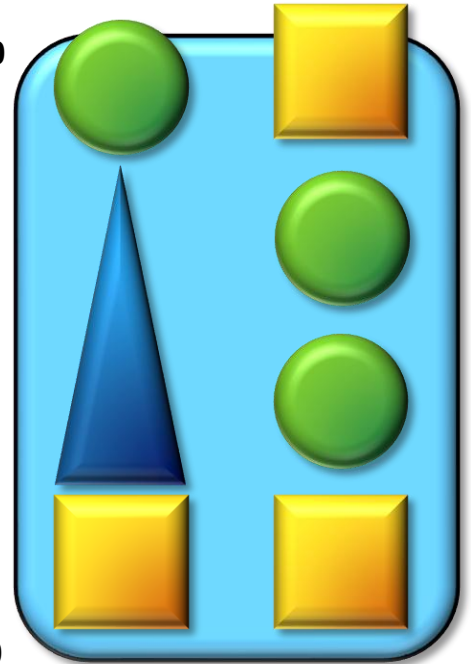


Either

15:30

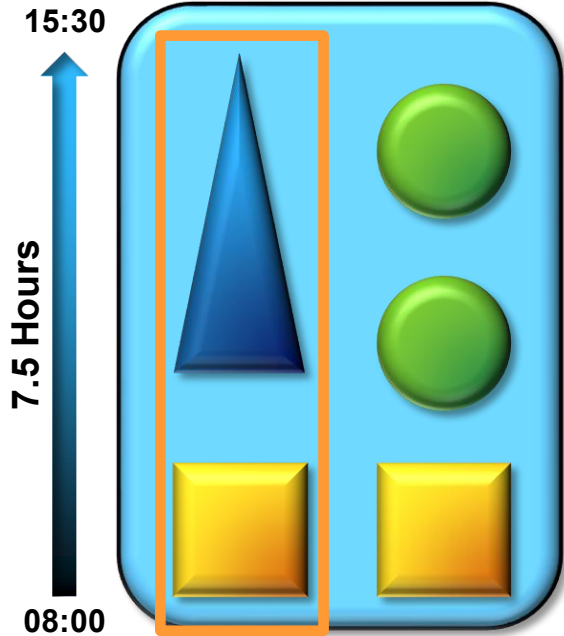
7.5 Hours

08:00



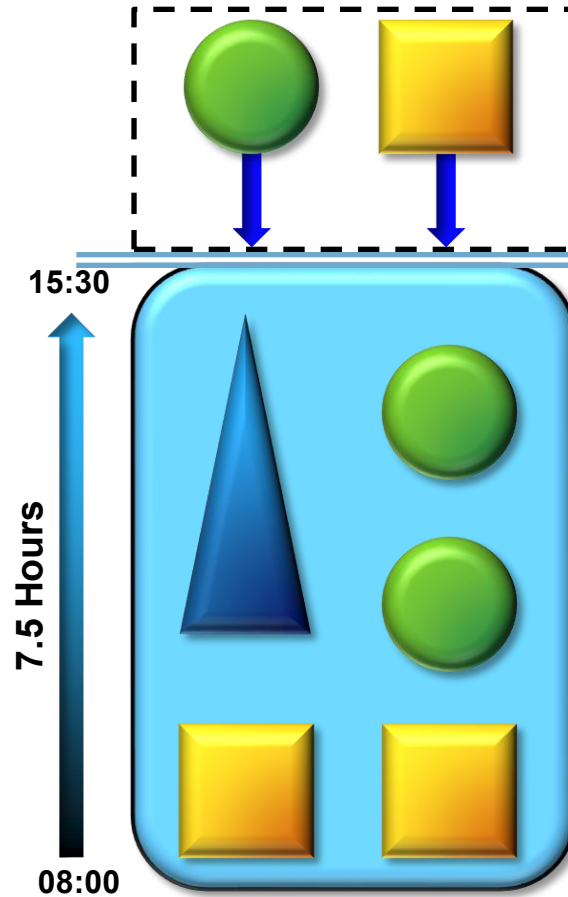
Desflurane

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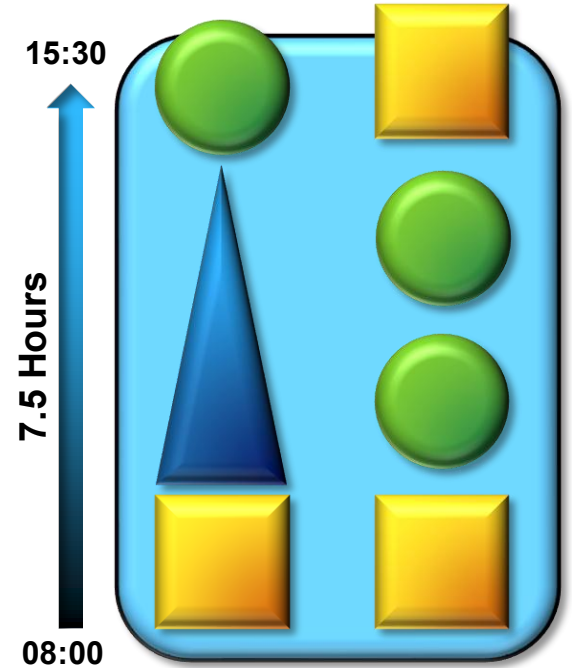
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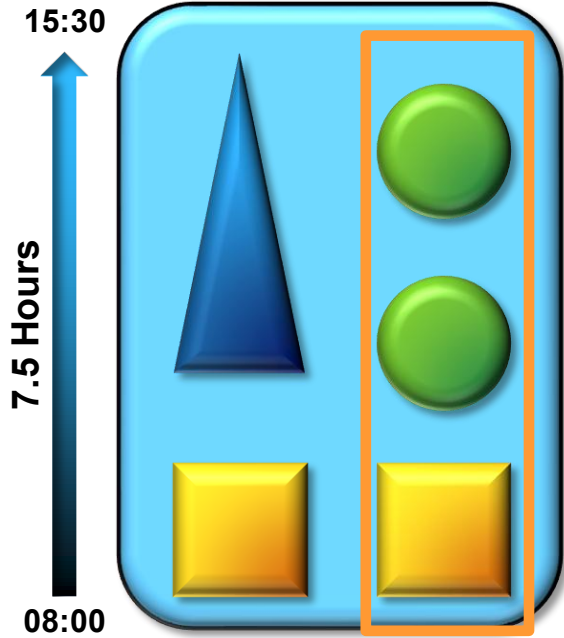
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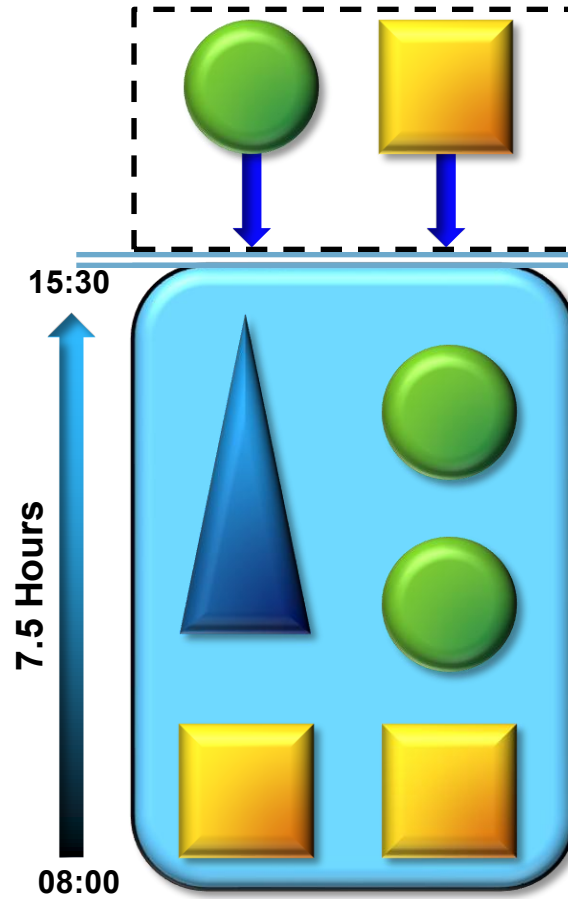
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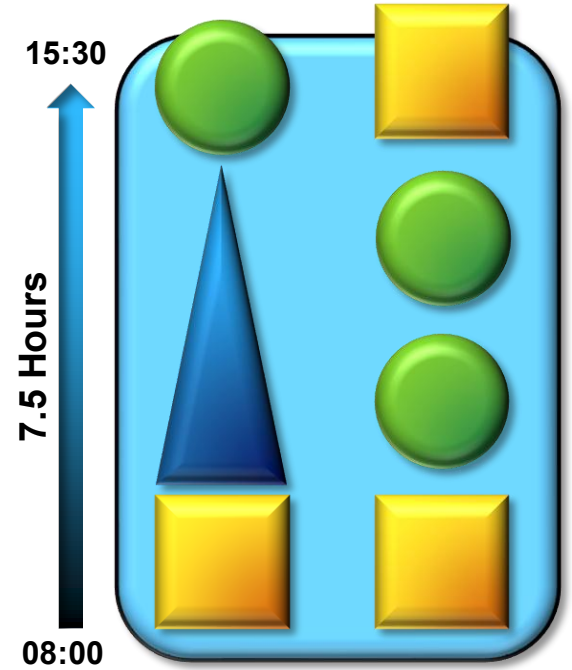
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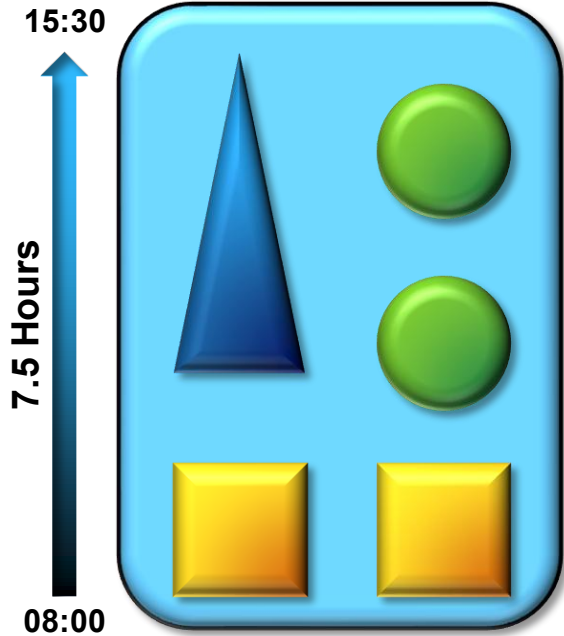
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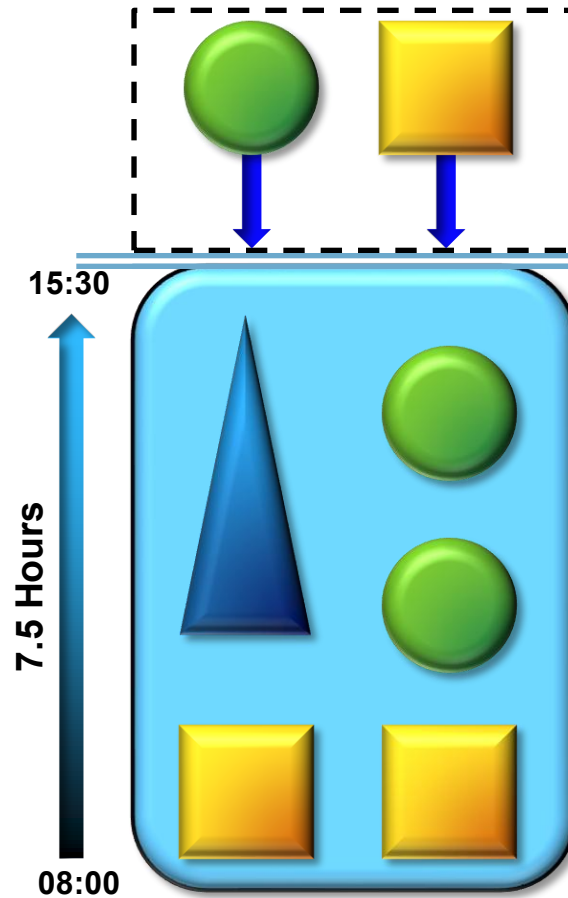
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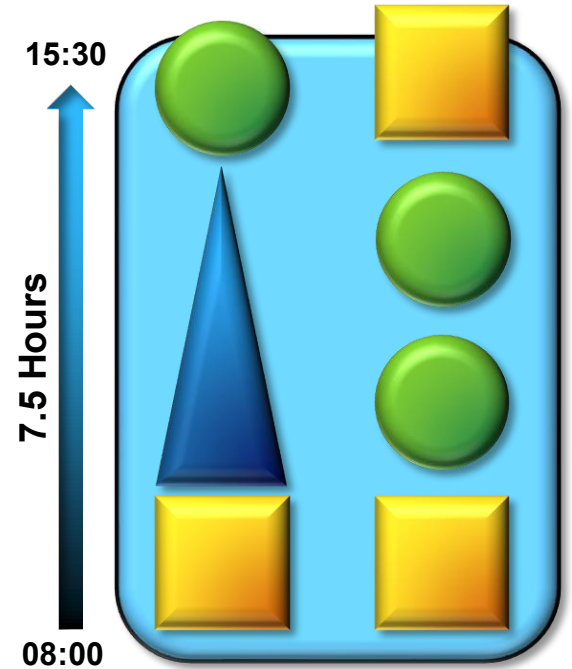
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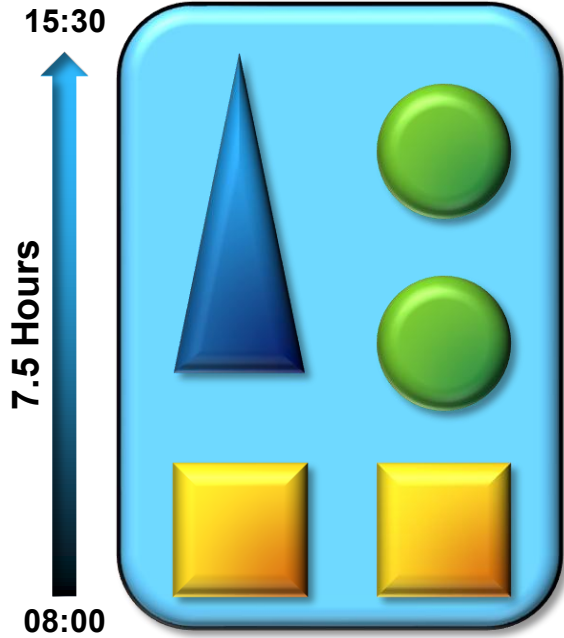
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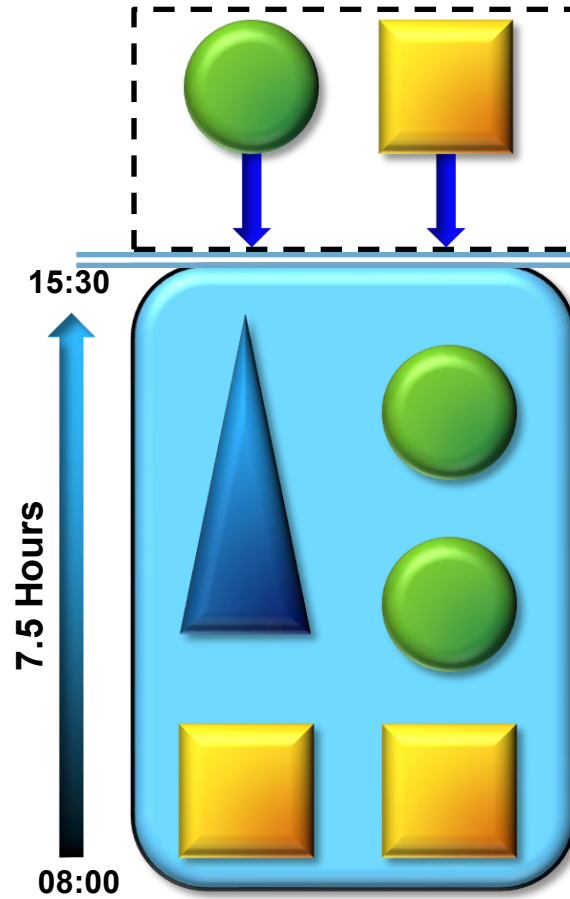
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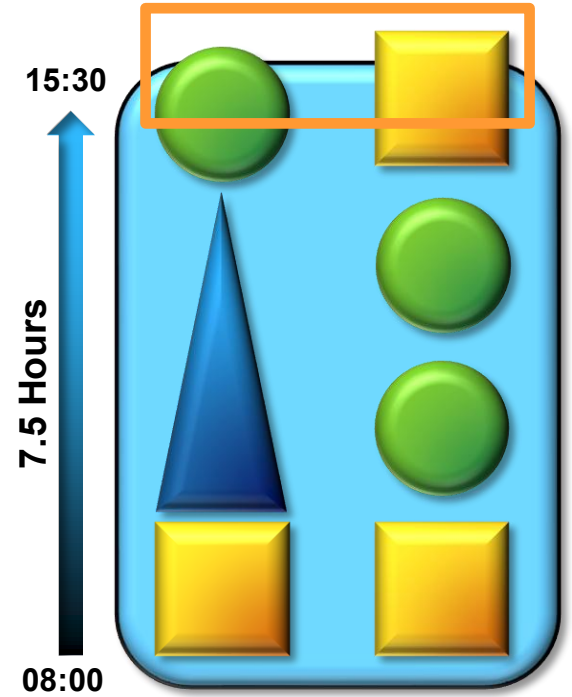
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Some Interventions' Benefits So Big That No Need for Simulation

- Change the type of anesthesia performed
- Example
 - Phase I PACU bypass rate for monitored anesthesia care patients was 90% at multiple ambulatory surgery centers
 - Monitored anesthesia care also reduced drug administration versus general anesthesia

Apfelbaum JL et al. Anesthesiology 2002



More Local Anesthesia

- Hand surgery cases requiring no more equipment than 2 surgical trays and 1 all-inclusive “hand pack”
 - Example: endoscopic carpal tunnel release
- Local anesthesia cases’ non-operative times (turnover + anesthesia-controlled time) averaged 18 minutes less than general anesthetic and 7 minutes less than monitored anesthesia care cases (both $P < 0.001$)

Caggiano NM et al. J Hand Surg Am 2015



More Regional Anesthesia

- At facilities where regional nerve block for one patient can be performed outside of OR while preceding case is being done

Brown MJ et al. Int J Health Care Qual Assur 2014

Gleicher Y et al. Reg Anesth Pain Med 2017



More Regional Anesthesia

- At facilities where regional nerve block for one patient can be performed outside of OR while preceding case is being done
 - Regional for outpatient knee surgery
 - ?
 - ?
 - ?
- Ways potentially to reduce costs



More Regional Anesthesia

- At facilities where regional nerve block for one patient can be performed outside of OR while preceding case is being done
- Regional for outpatient knee surgery
 - Drug costs are less [definitely no more]
 - Averaged 9 minutes less anesthesia controlled time than general anesthesia
 - 87% of patients bypassed phase I PACU

Williams BA et al. Anesthesiology 2000 and 2002

Dexter F et al. Periop Care Oper Room Manag 2023

Impact of the Reduced Anesthesia-Controlled Time

- 9 min ↓ anesthesia controlled time vs. GA
- No difference in surgical time versus GA
- Overall reduction unlikely large enough to reduce OR costs
- Definitely no increase in OR costs

Dexter F et al. Anesth Analg 1995, 2003

Dexter F et al. Reg Anesth Pain Med 1998

Williams BA et al. Anesthesiology 2000



Impact of 87% of Patients Bypassing Phase I PACU

- Reduced costs not just by reducing time to discharge by 34 min, but by each nurse caring for 3 rather than 2 patients
- Such reductions more than enough to result in financially important reductions in PACU staffing costs when done on a long-term basis

Williams BA et al. Anesthesiology 2002

Dexter F et al. Anesth Analg 1999



Hospitals 100% Patients Bypass Because no Phase I PACU

- 16 successive patients for laparoscopic gynecologic surgery with endotracheal intubation for general anesthesia at typical Japanese hospital with no phase I PACU versus University of Iowa

Thenuwara KN et al. Can J Anesth 2018



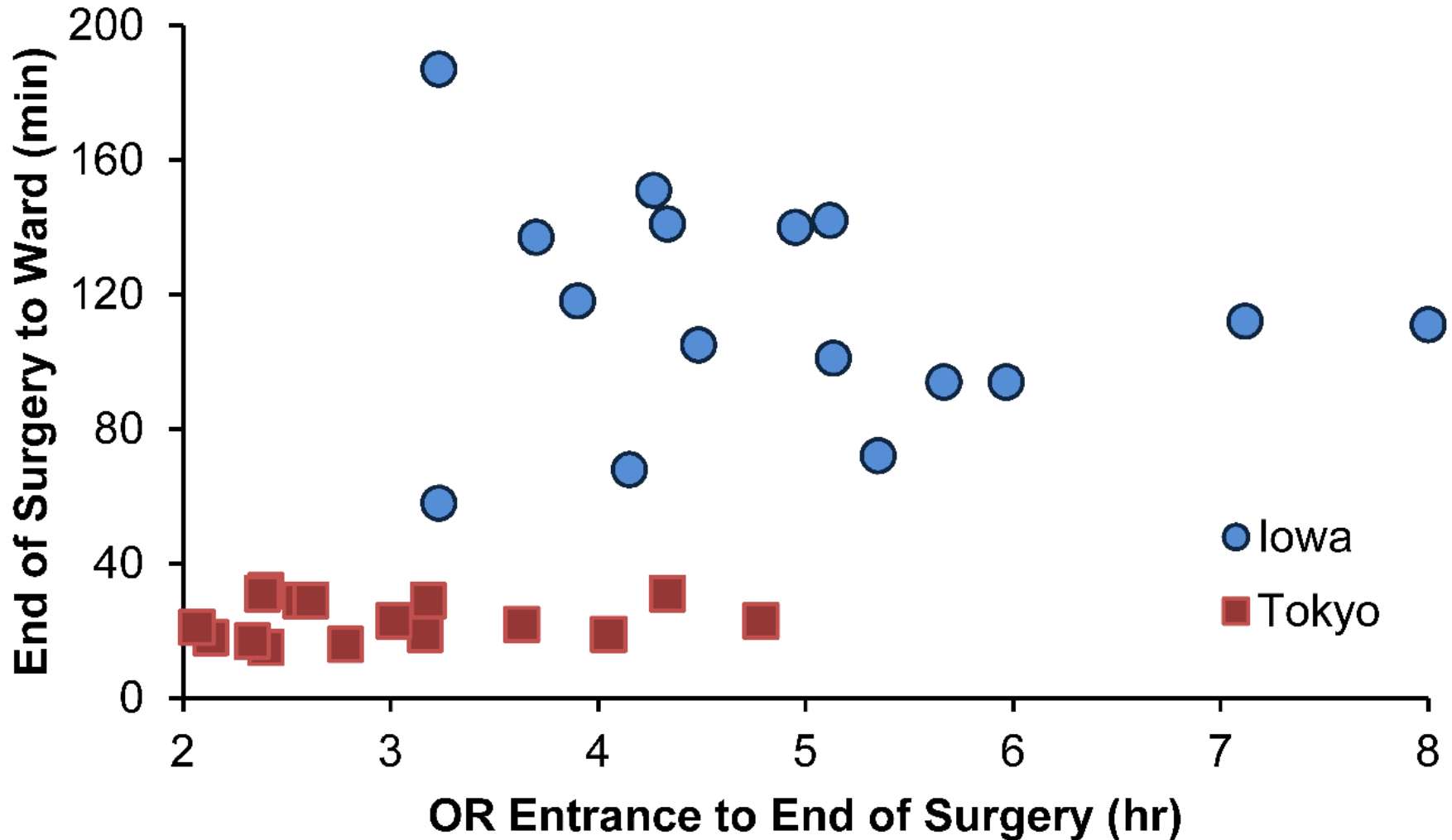
Hospitals 100% Patients Bypass Because no Phase I PACU

- 16 successive patients for laparoscopic gynecologic surgery with endotracheal intubation for general anesthesia at typical Japanese hospital with no phase I PACU versus University of Iowa
- Every patient Shin-yurigaoka General Hospital had briefer time from end of surgery to ward than every such patient at University of Iowa ($P < 0.001$)

Thenuwara KN et al. Can J Anesth 2018



Hospitals 100% Patients Bypass Because no Phase I PACU



Hospitals 100% Patients Bypass Because no Phase I PACU

- While controlling for duration of surgery, estimated mean recovery time at the Tokyo hospital was 81.2% faster than at University of Iowa (95% CI 72.7% to 87.1%, $P < 0.001$)

Thenuwara KN et al. Can J Anesth 2018



Hospitals 100% Patients Bypass Because no Phase I PACU

- While controlling for duration of surgery, estimated mean recovery time at the Tokyo hospital was 81.2% faster than at University of Iowa (95% CI 72.7% to 87.1%, $P < 0.001$)
- BIS monitor, target-controlled propofol infusion, and remifentanyl versus sevoflurane or isoflurane and hydromorphone

Thenuwara KN et al. Can J Anesth 2018



Hospitals 100% Patients Bypass Because no Phase I PACU

- Mean times from end of surgery to OR exit 1.9 minutes briefer at different Japanese hospital than University of Iowa ($P < 0.0001$)
- However, 100% of $N=699$ patients discharged from OR directly to surgical ward versus Iowa 97% of $N=785$ to phase I PACU, rest to ICU
 - No phase I PACU care even though all patients' gynecological surgery duration ≥ 4 hours

Sugiyama D et al. Anesth Analg 2021



Hospitals 100% Patients Bypass Because no Phase I PACU

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- However, 100% of $N=699$ patients discharged from OR directly to surgical ward versus Iowa 97% of $N=785$ to phase I PACU, rest to ICU
- Prolonged extubations were 6% versus 39%, respectively, and same among subset patients with desflurane/remifentanil versus neither



Review – Summarize the Facts of the Talk



List Priorities to Monitor to Assess Anesthesia Efforts at Reducing Costs



List Priorities to Monitor to Assess Anesthesia Efforts at Reducing Costs

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Additional Information on Operating Room Management

- www.FranklinDexter.net/education.htm
 - Example reports with calculations
 - Lectures on day of surgery decision making, PACU staffing, OR allocation and staffing, anesthesia staffing, financial analysis, comparing surgical services among hospitals, and strategic decision making
- www.FranklinDexter.net
 - Comprehensive bibliography of peer reviewed articles in operating room and anesthesia group management