Operational Decision-Making on the Day Before and the Day of Surgery

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Operational Decision-Making on the Day Before and the Day of Surgery

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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)

Lecture 1 – Use of Ordered Priorities for Decision Making

Format of Training

- 1.5 hr to complete the scenarios
  - If you have a question not precisely matching a scenario, write it down, and wait until the end
  - Scenario 8 depends on scenario 6, which depends on scenario 4, and so forth
  - Many questions will be covered toward the end
- Record each answer and score if right/wrong
  - If "obvious," then will get all correct

Format of Training

- As you "Record your answer," count the number of questions answered correctly
  - No credit for questions not answered
- At end of lecture, submit your count in poll
- Evaluate how well you and your colleagues can predict results of management studies
  - All questions have 1 correct (best) answer

Dexter F et al. Anesthesiology 2004

Dexter F et al. Anesth Analg 2016

Develop Policy Guideline for Picking Up Visitor at Airport

- Spend 5 minutes to write a corporate policy for arriving at an airport sufficiently early to pick up a visiting speaker
  - Scheduled arrival time is 5 PM

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  - Scheduled arrival time is 5 PM
- Let the policy be flexible enough for workers to enjoy their work
  - Ann parks in Ramp A, because it is closer to the Starbuck's – she wants to get a cappuccino while waiting

Develop Policy Guideline for Picking Up Visitor at Airport

- Prevent future embarrassing events
  - Mary "borrowed" her neighbor's sports car, and drove at an unsafe speed, reportedly to make sure that she arrived on-time
  - Betsy drove at a safe speed, but arrived at 7 AM, even though the visitor was not arriving until 5 PM
  - Jim was so concerned about terrorism, that he never showed up stranding the visitor

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- Policy is that employees will make decisions in accordance with a set of ordered priorities
  - Personal preferences
  - Minimize minutes showing up early
  - Safety
  - Reduce minutes that visitor has to wait
  - Show up (do not cancel)

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➢ Order the above 5 priorities based on the preceding 4 scenarios (Ann, Mary, Betsy, Jim)

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Moral About Policies for Operational Decision-Making

- Policy for operations usually results in a set of ordered priorities
- Ordered priorities cannot be chosen by consensus, because including the priorities to avoid absurd decisions results in sufficient precision that the decision is already made

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- Policy for operations usually results in a set of ordered priorities
- Ordered priorities cannot be chosen by consensus, because including the priorities to avoid absurd decisions results in sufficient precision that the decision is already made
- ➢ Ordered priorities cannot be chosen well in a meeting with people "thinking" about priorities

Moral About Policies for Operational Decision-Making

- Group-level decision-making has little to no role in effective operational OR management decision-making

Prahl A et al. Anesth Analg 2013

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  - Autocratic decision-making otherwise

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Moral About Policies for Operational Decision-Making

- Group-level decision-making has little to no role in effective operational OR management decision-making
  - Autocratic decision-making otherwise
  - ➢ Consultative decision-making when other stakeholders (subordinates) have also received education including knowledge of vocabulary

Prahl A et al. Anesth Analg 2013

Topics of Lecture 1

- Policy on when to arrive at airport
- Decision-making based on ordered priorities
  - ➢ Definitions
- Scenarios to apply priorities
- First-come first-served
- Reducing tardiness, not % cases delayed
- Bin packing

Wachtel RE, Dexter F. Anesth Analg 2013

Definitions of *Staffing*, *Staff Scheduling*, and *Staff Assignment*

- Staffing (months ahead)
  - Department of Anesthesiology plans 3 ORs in the main surgical suite for urgent cases between Monday 6 PM and Tuesday 7 AM
- Staff scheduling (weeks ahead)
  - Jill is scheduled Monday 8 AM to 6 PM
  - James is scheduled Monday starting at 6 PM
- Staff assignment (0-1 days ahead)
  - Alex is assigned to OR 3

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Example of *Tardiness*

- Three cases of same procedure are scheduled
- Expected OR times are 2 hr
- Expected turnover times are 30 min
- Scheduled start times: 8 AM, 10:30 AM, 1 PM
- First case entered the OR at 8:20 AM
- At 9 AM, expected ***tardiness*** of OR is 40 min
  - The 40 min = 20 min late + 20 min late
    - Two 20 min because there are two cases following the first case that started late

Example of *Under-Utilized OR Time*

- Staffing is planned from 7:15 AM to 3:30 PM
- An OR's last case of the day ends at 1:30 PM
- There are 2 hours of under-utilized OR time
  - Under-utilized time is from 1:30 PM to 3:30 PM

Strum DP et al. Anesthesiology 1999

Example of *Over-Utilized OR Time*

- OR staffing is planned from 7 AM to 4 PM
- OR's last case of the day ends at 6 PM
- There are 2 hours of *over-utilized OR time*
  - Over-utilized OR time is from 4 PM to 6 PM

Precise Meaning of "Maximize OR Efficiency"

Inefficiency of use of OR time ($) =

(Cost per hour of under-utilized OR time)
× (hours of under-utilized OR time)

+ (Cost per hour of over-utilized OR time)
× (hours of over-utilized OR time)

Strum DP et al. J Med Syst 1997

Why OR Efficiency and Not Labor Costs?

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- Costs differ depending on basis for decision
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  - Even when nursing, anesthesia, and surgeons follow the same ordered-priorities, if based on labor costs they make different decisions

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➢ Decisions based on OR efficiency invariant to these issues

Scenario 1 – Can Working Fast Increase OR Efficiency?

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- Staffing is planned from 8 AM to 3:30 PM
- There are estimated to be 8.5 hr of cases
- Anesthesiologist gets every IV first stick, A lines and C lines first stick, and does a fiberoptic intubation in 8 minutes
- OR finishes at 3:30 PM, instead of 4:30 PM
- Has anesthesiologist increased OR efficiency?

Scenario 1 – Can Working Fast Increase OR Efficiency?

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
  - On the day of surgery, the cost of an hour of under-utilized OR time is negligible relative to the cost of an hour of over-utilized OR time

Meaning of Maximizing OR Efficiency on Day of Surgery

Inefficiency of use of OR time ($) ≅

~~(Cost per hour of under-utilized OR time)~~

× (hours of under-utilized OR time)

+ (Cost per hour of over-utilized OR time)

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Dexter F, Traub RD. Anesth Analg 2002

Dexter F et al. Anesthesiology 2004

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  - Maximize OR efficiency on the day of surgery by minimizing hours of over-utilized OR time

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- Implication
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Scenario 1 – Can Working Fast Increase OR Efficiency?

- Scenario
  - Staffing was planned from 8 AM to 3:30 PM, which is 7.5 hr
  - Fast anesthesiologist finished cases in 7.5 hr instead of in the expected 8.5 hr
    - Finished at 3:30 PM instead of at 4:30 PM
    - Had 0 hours of over-utilized time instead of 1 hour of over-utilized time

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    - Had 0 hours of over-utilized time instead of 1 hour of over-utilized time
  - ➢ Fast anesthesiologist increased OR efficiency by preventing 1 hr of over-utilized OR time

Format of Training

- As you "Record your answer," count the number of questions answered correctly
  - No credit for questions not answered

➢ Keep track of your count of correct answers

- At end of lecture, submit your count in poll
- Evaluate how well you and your colleagues can predict results of management studies
  - All questions have 1 correct (best) answer

Dexter F et al. Anesthesiology 2004

Scenario 1 – Can Working Fast Increase OR Efficiency?

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Good (rational) OR management operational decision-making is highly sensitive to the staffing for each OR, and requires knowing the staffing for each OR

Organizational Decision Making by Ordered Priorities

- Listed in order of priority
  1. Patient *safety* is preeminent
  2. Every surgeon has open *access* to OR time on *Any* future *Workday* for elective cases
  3. Maximize OR *efficiency* by minimizing hours of over-utilized OR time
  4. Reducing *patient waiting* by reducing expected tardiness for elective cases and waiting for urgent cases
  5. *Personal satisfaction*

Scenario 2 – Anesthesiologist Reduces Turnover Times

- Staffing is planned from 7:15 AM to 3:30 PM
- Anesthesiologist is assigned to supervise resident physicians in OR 3 and OR 4
- These ORs have just finished their first cases
- The second and last case of the day in OR 3 is expected to be finished at 2:30 PM
- The second and last case of the day in OR 4 is expected to be finished at 4:30 PM
- Which OR should anesthesiologist start next?

Scenario 2 – Anesthesiologist Reduces Turnover Times

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency*
  - OR 3 expected 0 hr of over-utilized OR time
    - Finish 2:30 PM, but staffing to 3:30 PM
  - OR 4 expected 1 hr of over-utilized OR time
    - Finish 4:30 PM, but staffing to 3:30 PM
- If the patient for OR 4 is ready, the anesthesiologist should start OR 4 first

Scenario 2 – Anesthesiologist Reduces Turnover Times

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- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is unaffected by the decision
  - OR 3 expected 0 over-utilized hours
  - OR 4 expected ~~1~~ ***0*** over-utilized hours
- *Patient waiting* is unaffected by the decision
  - Last case of the day in both ORs
- *Personal satisfaction* may be affected
  - Whatever anesthesiologist thinks best

Scenario 2 – Anesthesiologist Reduces Turnover Times

- Moral
  - To make good (rational) OR management operational decisions, you need to know the staffing planned for each OR
    - Calculated based on minimizing the inefficiency of use of OR time

Dexter F et al. Anesth Analg 2016

Scenario 3 – Which OR Should Housekeeper Clean First?

- Right when two ORs are finishing their first cases of the day on time, only one person is free to clean the two ORs
- Last case of the day in OR 12 is expected to end at 2 PM
- Last case of the day in OR 14 is expected to end at 4:30 PM
- Staffed hours are from 7 AM to 3:30 PM
- Which OR should housekeeper clean first?
  - Follow the ordered priorities

Scenario 3 – Which OR Should Housekeeper Clean First?

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is affected by the decision
  - OR 12 expected 0 hr of over-utilized OR time
    - Finish 2 PM, while plan staffing to 3:30 PM
  - OR 14 expected 1 hr of over-utilized OR time
    - Finish 4:30 PM, while plan staffing to 3:30 PM
- Cleaning OR 14 first is likely to increase OR efficiency

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- Open *access* is unaffected by the decision
- *OR efficiency* is unaffected by the decision
  - OR 12 expected 0 over-utilized hours
  - OR 14 expected ~~1.5~~ ***0*** over-utilized hours
- *Patient waiting* is unaffected by the decision
  - Last case of the day in each OR
- *Personal satisfaction* is basis for decision

Scenario 3 – Which OR Should Housekeeper Clean First?

- Why reducing hours of over-utilized OR time, instead of reducing labor costs?

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- Why reducing hours of over-utilized OR time, instead of reducing labor costs?
- Same decision made regardless of …
  - Housekeeper's scheduled hours that day
  - Housekeeper's total hours for the week
  - Collective bargaining agreements
  - How nursing schedules and assigns staff
  - How anesthesia schedules and assigns staff

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Review – Summarize the Facts of the Talk

Expectations for a Quality OR Manager

Expectations for a Quality OR Manager

- Controls efficiency of use of OR time?
- Controls labor costs?
- Controls staffing?
- Makes decisions to reduce inefficiency of use of OR time?

Scenario 4 – Calling For the Next Patient

- Two ORs call for their next cases, but only one person is free to prepare the patients
- Both ORs are 10 min behind schedule
- The four remaining cases in OR-A are estimated to end at 2 PM
- The one remaining case in OR-B is estimated to end at 4 PM
- Staffing is planned from 7 AM to 6 PM
- Prepare which patient first?

Scenario 4 – Calling For the Next Patient

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is unaffected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 0 over-utilized hours
- *Patient waiting* is affected by decision
  - OR-A expected total tardiness is 40 min
  - OR-B expected total tardiness is 10 min
- Prepare the patient for OR-A first

Scenario 4 – Calling For the Next Patient

- Two ORs call for their next cases, but only one person is free to prepare the patients
- Both ORs are currently on schedule
- The four remaining cases in OR-A are estimated to end at 2 PM
- The one remaining case in OR-B is estimated to end at 4 PM
- Staffing is planned from 7 AM to ~~6 PM~~ ***3*** PM
- Prepare which patient first?

Scenario 4 – Calling For the Next Patient

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is affected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 1 over-utilized hours
- Prepare the patient for OR-B first

Scenario 4 – Calling For the Next Patient

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is affected by the decision
  - OR-A expected 0 over-utilized hours
  - OR-B expected 1 over-utilized hours
- Prepare the patient for OR-B first

Good (rational) OR management operational decision-making is highly sensitive to the staffing planned for each OR, and requires knowing the staffing planned for each OR

Scenario 5 – Selecting Patient to Start Recovery in OR

- Staffing is planned from 7:15 AM to 3:30 PM
- At 2:20 PM, OR 11 reports that they will bring their last patient of day to PACU in 10 min
  - OR 11 has no additional cases to be performed
- At 2:25 PM, OR 21 wants to bring their 2nd to last patient of the day to the PACU in 10 min
- The PACU can currently only accept 1 extra patient while satisfying ASPAN standards
- What should PACU clerk or nurses do?

Scenario 5 – Selecting Patient to Start Recovery in OR

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* likely is affected by the decision
  - Depending on the duration of the last case in OR 21, there may be over-utilized OR time
- *Patient waiting* is affected by the decision
  - Contact OR 11 and have them start recovering patient in the OR

Scenario 5 – Selecting Patient to Start Recovery in OR

- Important principle is that this rational decision-making is sufficient for decision making on the day of surgery

Dexter F et al. Anesthesiology 2004

Scenario 5 – Selecting Patient to Start Recovery in OR

- Important principle is that this rational decision-making is sufficient for decision making on the day of surgery
- ➢ Practically though of limited usefulness, since more effective to avoid the problem months ahead by planning optimal distribution of PACU nurses among hours of the day

Dexter F et al. J Perianesth Nurs 2005
Ehrenfeld JM et al. Anesth Analg 2013

Scenario 6 – Decision Based on Patient Safety

- Staffing is planned from 7:15 AM to 3:30 PM
- At 12:15, one OR is finished its elective cases
- All other ORs expected to be busy until 5 PM
- Transplant surgeon called three hours ago for cadaveric kidney transplant
  - Surgeon's assessment is that the remaining safe cold ischemic time is 10 hr
- Vascular surgery patient has ruptured AAA
- How sequence the cases based on the ordered priorities?

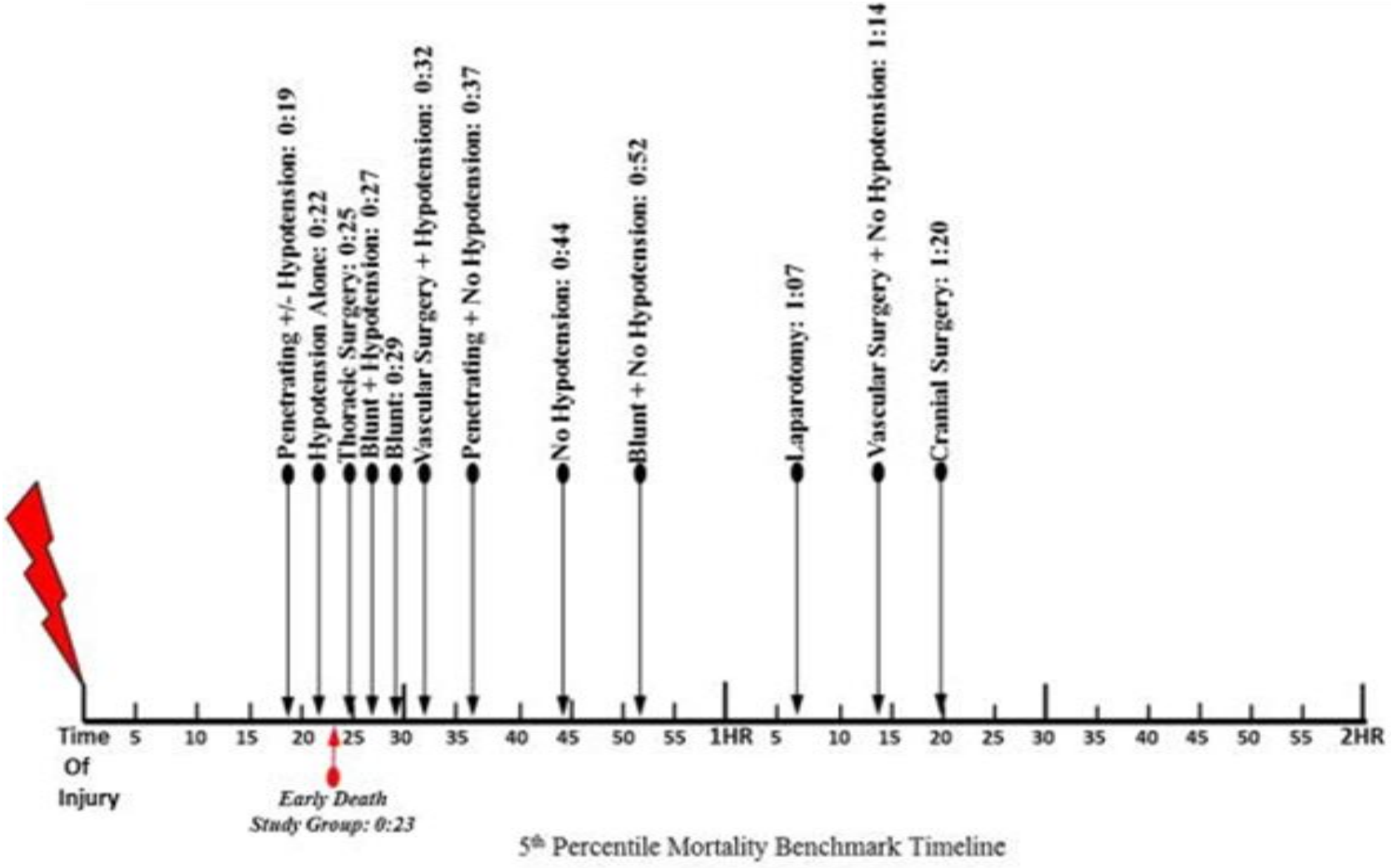
Scenario 6 – Decision Based on Patient Safety

- *Patient safety* is affected by decision
  - Ruptured AAA is done first
- Surgeon knows date and time of occurrence of event that requires urgent surgery or equivalently when symptoms began
  - Other examples are fracture for hip or right lower quadrant pain for appendectomy
- Hours from randomized/observational studies

Dexter F et al. J Clin Monit Comput 1999

Charalambous CP et al. Injury 2005

Scenario 6 – Decision Based on Patient Safety



Remick KN et al. J Trauma Acute Care Surg 2014

Scenario 7 – Moving Cases

- Staffing is planned from 7:15 AM to 3:30 PM
- OR 1 finishes last case of the day at 1:30 PM
- OR 2 is running behind
  - Its last case, scheduled from 2 PM to 3:30 PM, will not start until 5 PM
  - Anesthesia and nursing team assigned to OR 1 can perform the case safely
  - Surgeon and patient are ready
- Move the last case in OR 2 into OR 1?

Scenario 7 – Moving Cases

- *Patient safety* is unaffected by the decision
- Open *access* is unaffected by the decision
- *OR efficiency* is affected by the decision
  - Case performed entirely in over-utilized OR time if case is not moved
  - Over-utilized OR time likely reduced by at least 1.5 hr if case is moved
  - Move the case from OR 2 to OR 1

Scenario 7 – Moving Cases

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- Open *access* is unaffected by the decision
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  - Case performed entirely in over-utilized OR time if case is not moved
  - Over-utilized OR time likely reduced by at least 1.5 hr if case is moved
  - Move the case from OR 2 to OR 1

➢ Moral: Cannot monitor over-utilized time *per se*

Scenario 8 – Teams Staying Late for Add-on Cases

- Hospital has one team to work past 3 PM
  - Team will not finish its case until 10 PM
- At 3 PM, all other ORs have recently finished
- There are two other 1.5 hr cases to be done, neither of which can medically wait until 10 PM, but both of which can wait to 6 PM
- What decision should be made?
  - Have one team stay late to do two cases sequentially, or have two teams stay late, each to do one case?

Scenario 8 – Teams Staying Late for Add-on Cases

- *Patient safety* is unaffected by the decision
  - Have to do the cases
- Open access is unaffected by the decision
  - Irrelevant since must care for the patients
- OR efficiency is unaffected by the decision
  - Perhaps slightly more over-utilized OR time by doing cases sequentially from the turnover
- Patient waiting is basis for the decision
  - Two teams stay late to do the cases

Scenario 8 – Teams Staying Late for Add-on Cases

- Patient safety is unaffected by the decision
  - Have to do the cases
- Open access is unaffected by the decision
  - Irrelevant since must care for the patients
- ➢ *OR efficiency* is unaffected by the decision
  - Perhaps slightly more over-utilized OR time by doing cases sequentially from the turnover
- Patient waiting is basis for the decision
  - Two teams stay late to do the cases

Scenario 8 – Teams Staying Late for Add-on Cases

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- ➢ *Patient waiting* is basis for the decision
  - Two teams stay late to do the cases

But, … Personal Satisfaction is Important for Retention …

- Scenario to understand why Personal Satisfaction must have lower priority than reducing patient and surgeon waiting

But, … Personal Satisfaction is Important for Retention …

- OR with 4 hr of under-utilized OR time
  - Anesthesiologist leaves for a 2 hr lunch break in between the surgeon's two cases
    - His personal satisfaction is higher priority than patient and surgeon waiting

Wang J et al. Anesth Analg 2013

But, … Personal Satisfaction is Important for Retention …

- OR with 4 hr of under-utilized OR time
  - Anesthesiologist leaves for a 2 hr lunch break in between the surgeon's two cases
    - His personal satisfaction is higher priority than patient and surgeon waiting

➢ Priorities apply to operational decision-making

  - On long term basis, if plan extra staffing, rarely must surgeons and patients wait
    - Decisions are then usually made based on personal satisfaction

Scenario 9 – Reducing Staffing for Satisfaction

- Planned staffing is 3 ORs from 6 PM to 7 AM for non-elective cases
- Two ORs expected to finish cases at 12 MN
- At 9:30 PM, third OR is finishing its case
- Third OR covered by backup anesthesiologist (clinical next day) and junior resident
- Sole pending case can wait safely > 8 hr
- Should backup anesthesiologist stay for case?

Scenario 9 – Reducing Staffing for Satisfaction

- Over-utilized OR time
  - Expect 0 hr of over-utilized OR time regardless of when start next case, unless were very long
- Patient and surgeon waiting
  - Reduced by starting case promptly
  - Start the case now

Scenario 9 – Reducing Staffing for Satisfaction

- Over-utilized OR time
  - Expect 0 hr of over-utilized OR time regardless of when start next case, unless were very long
- Patient and surgeon waiting
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➢ Why important?

Scenario 9 – Reducing Staffing for Satisfaction

- Over-utilized OR time
  - Expect 0 hr of over-utilized OR time regardless of when start next case, unless were very long
- Patient and surgeon waiting
  - Reduced by starting case promptly
  - Start the case now
- Why important?
- ➢ When and how should personal satisfaction of backup anesthesiologist be addressed?

Scenario 9 – Reducing Staffing for Satisfaction

- Personal satisfaction of backup anesthesiologist is affected by anesthesia department's staff scheduling and assignment
  - Address such issues with Vice Chair of Clinical Affairs or equivalent at appropriate time
- Staffing (i.e., OR allocations) is calculated from expected workload months in advance
  - Nursing, Anesthesia, and Surgical departments can then plan their staff scheduling and assignments independently

Scenario 10 – When Cases Exceed Staffing

- Saturday and Sunday staffing is 3 ORs x 24 hr for non-elective cases

Dexter F et al. Anesth Analg 2016

Scenario 10 – When Cases Exceed Staffing

- Saturday and Sunday staffing is 3 ORs x 24 hr for non-elective cases
- Not once in years have 3 ORs run non-stop for 24 hr on either Saturday or Sunday
- Under what circumstances would a 4th OR be opened on a Saturday?
  - Base list on the ordered priorities

Scenario 10 – When Cases Exceed Staffing

- *Patient safety*
  - With three ORs, a case could not reliably start by when the surgeon says it needs to start
- Open *access* to OR time
  - No effect, since do all the cases
- *OR efficiency*
  - Never open 4th OR other than for safety reasons, because would first fully fill the 3 ORs, which has never happened

Scenario 10 – When Cases Exceed Staffing

- *Patient safety*
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- Open *access* to OR time
  - No effect, since do all the cases
- *OR efficiency*
  - Never open 4th OR other than for safety reasons, because would first fully fill the 3 ORs, which has never happened

➢ **Staffing ≠ maximum # ORs at same time**

Scenario 11 – Change in Patient Condition

- Staffing is 3 ORs from 6 PM to 7 AM
  - Two ORs will not finish cases until after 11 PM
- At 5:45 PM, two other ORs just finished cases
- At 6:00 PM, transporter leaves to pickup patient to undergo repair of elbow fracture
  - Medical deadline is to start case within 24 hr
- At 6:05 PM, OR notified of patient with expanding pseudoaneurysm of femoral artery
- Start both cases or delay start elbow fracture case?

Scenario 11 – Change in Patient Condition

- *Patient safety* is unaffected by decision
  - Orthopedic case can wait safely until the vascular case has been completed
- Open *access* to OR time unaffected by decision
  - Will do both cases
- *OR efficiency* is affected by decision
  - If do both cases right-away, elbow fracture case would be result in over-utilized OR time
  - Only start the pseudoaneurysm case

Scenario 11 – Change in Patient Condition

- Reevaluate decision whenever …
  - New case is scheduled
  - OR times are updated
    - On-going or pending cases
  - Condition of patient waiting changes

Scenario 11 – Change in Patient Condition

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- At 6:00 PM, transporter leaves to pickup patient to undergo repair of elbow fracture
  - Medical deadline is to start case within 24 hr
- At 6:05 PM, OR notified of patient with expanding pseudoaneurysm of femoral artery
- At 6:10 PM, notify orthopedic resident of delay

Scenario 11 – Change in Patient Condition

- At 6:15 PM, pseudoaneurysm case starts
- At 6:15 PM, orthopedic attending updates medical deadline for case to start within 1 hr
  - Anesthesiologist's judgment is that explanation is inconsistent with evidence-based medical practice
- Unclear if start case for elbow fracture too
  - Unclear how and when address attending surgeon's basis for changing medical deadline

Scenario 11 – Change in Patient Condition

- *Patient safety* is basis for decision
  - My opinion
    - Start elbow fracture case promptly
    - OR team stays late as over-utilized OR time
- Next day, anesthesiologist reviews case with Department of Anesthesia's Vice Chair of Clinical Affairs (or equivalent person)
  - Basis for complaint is that decision was not made based on institution's ordered priorities

Review – Summarize the Facts of the Talk

Create an Expectation for a New Perioperative Medical Director

Create an Expectation for a New Perioperative Medical Director

- Does medical director choose the staffing?
  - What's the responsibility of the medical director about staffing?
- Can medical director be responsible for staff scheduling?
  - Who does the staff scheduling?
- Can medical director be responsible for over-utilized time? Patient and surgeon waiting?
  - What precisely can the medical director be responsible for assuring?

Three More Concepts to be Learned in Lecture 1

- First-come first-served rarely can be applied systematically in hospitals
- Why reduce tardiness as end-point for patient waiting on day of surgery?
- Principles of bin packing add-on cases

Dexter F et al. Anesthesiology 2004

Scenario 12 - First-Come First-Served at Surgical Suites

- Staffing is planned from 7 AM to 3:30 PM
- At 7 AM, urgent case has to start right away
  - Add-on case plus turnover will take 1.5 hr
- Case can be done safely in any OR
- Last cases of day likely will end at 1 PM for OR 1 and OR 2, and 3:30 PM in other ORs
- OR 1 has four short otolaryngology cases
- OR 2 has one long neurosurgery case
- Do the case in which OR?

Scenario 12 - First-Come First-Served at Surgical Suites

- OR 1 or OR 2 to minimize over-utilized hours
- OR 1: total tardiness of 6.0 hr
  - 4 patients each waiting 1.5 hr
- OR 2: total tardiness of 1.5 hr
  - 1 patient waiting 1.5 hr
- Perform urgent case in OR 2

Scenario 12 - First-Come First-Served at Surgical Suites

- OR 1 or OR 2 to minimize over-utilized hours
- OR 1: total tardiness of 6.0 hr

  4 patients each waiting 1.5 hr
- OR 2: total tardiness of 1.5 hr

  1 patient waiting 1.5 hr
- Perform urgent case in OR 2

➢ Cannot have answered question by first-come first-served unless relied on knowing when the elective cases were originally scheduled

Scenario 12 - First-Come First-Served at Surgical Suites

- Be on the look-out for people applying first-come first-served incorrectly
- In healthcare virtually never do you have one group of patients, and thus rarely can first-come first-served be applied rationally

Three More Concepts to be Learned in Lecture 1

- First-come first-served rarely can be applied systematically in hospitals
  - ➢ Why reduce tardiness as end-point for patient waiting on day of surgery?
- Principles of bin packing add-on cases

Wachtel RE, Dexter F. Anesth Analg 2009

Reduce Percentage of Cases with Delayed Start Time?

- Staffing is planned from 7 AM to 3:30 PM
- At 7 AM, urgent case has to start right away
- OR 1 has four short otolaryngology cases
- OR 2 has one long neurosurgery case
- Hold OR 1 and OR 2 until 7:10 as decide

Reduce Percentage of Cases with Delayed Start Time?

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  - ➢ Regardless of whether case into OR 1 or OR 2, all cases are expected to have some tardiness

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- Hold OR 1 and OR 2 until 7:10 as decide
- Regardless of whether case into OR 1 or OR 2, all cases are expected to have some tardiness

➢ Which ordered priority would be basis for decision if aim to reduce % cases delayed?

Reduce Percentage of Cases with Delayed Start Time?

- *Patient safety*
  - Start the case right away
- Open *access* is unaffected by the decision
- *OR efficiency*
  - Choose OR 1 or OR 2
- *Patient waiting* is unaffected by the decision
  - All (100%) of cases expected to be delayed regardless of the decision
- *Personal satisfaction* is basis for decision

Reduce Percentage of Cases with Delayed Start Time?

- Scenarios can be created with equivalent unusual solutions by having any percentage threshold for delay
- Reducing tardiness has advantage of not ignoring cases that have tardiness already exceeding threshold

Three More Concepts to be Learned in Lecture 1

- First-come first-served rarely can be applied systematically in hospitals
- Why reduce tardiness as end-point for patient waiting on day of surgery?
  - ➢ Principles of bin packing add-on cases

Dexter F et al. Anesthesiology 1999
Dexter F, Traub RD. Anesth Analg 2002
Dexter F et al. Anesthesiology 2004
Shi P et al. Anesth Analg 2016

Bin Packing Surgical Cases

- Staffing planned from 7 AM to 5 PM
- Time remaining in ORs at 2 PM
  - 3 hours in add-on OR [available immediately]
  - 2 hours in OR 2 [available in 1 hr]
  - 1 hour in OR 3 [available in 2 hr]
  - 0 hours in all other ORs
- Three add-on cases listed in sequence of submission: 0.7 hr, 2.9 hr, 1.8 hr
- All can safely wait a few hours
- Perform cases in what sequence?

Bin Packing Surgical Cases

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Bin Packing Surgical Cases

- Sort the cases based on estimated duration from longest to shortest
  - Consider the cases in this descending order
  - Longest add-on case is assigned first
- Assign each case to OR meeting two criteria
  - Has no restrictions on equipment or personnel preventing the case from being put into the OR
  - Sufficient extra time available for the new case

Bin Packing Surgical Cases

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Safety

Bin Packing Surgical Cases

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Why?

Reason for Add-on Surgical Case Scheduling Result

- Sort the cases based on estimated duration from longest to shortest
  - Consider the cases in this descending order
  - Longest add-on case is assigned first
- Assign each case to OR meeting two criteria
  - Has no restrictions on equipment or personnel preventing the case from being put into the OR
  - Sufficient extra time available for the new case

Why?

Reason for Add-on Surgical Case Scheduling Result

- On average, only 1/5 ORs with scheduled cases will have time available for add-on case
- Average time remaining in these ORs each day will be around 1.3 hr, with large SD 1.6 hr
- Average OR time of add-on cases including their turnover times around 3.4 hr (SD 1.7 hr)
  - Long, since add-on case scheduling applies to cases at hospitals, rarely outpatient facilities

Dexter F et al. Anesthesiology 1999

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- Average OR time of add-on cases including their turnover times around 3.4 hr (SD 1.7 hr)
  - Long, since add-on case scheduling applies to cases at hospitals, rarely outpatient facilities

➢ Because 0 or 1 add-on cases per OR not designated for add-on cases

Bin Packing Surgical Cases

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  - Sufficient extra time available for the new case

➢ Reduces the hours of over-utilized OR time!

Scenario 13 – Applying Bin Packing Principles

- Staffing is planned from 7 AM to 5 PM
- Current time is 6:50 AM
- Add-on case OR has on-going case expected to end at 9 AM
- There is currently only one add-on case queued, estimated time 2 hours
- Surgeon does not care when the case starts, but wants to know its start time, now
- Case goes into add-on case OR starting around 9:30 AM or starts at 2:45 PM in OR 6?

Scenario 13 – Applying Bin Packing Principles

- Based on preceding bin packing results, both likely equally good choices
  - Balance of multiple factors including
    - Chance another long add-on case scheduled
    - Chance cancellation or delay, especially among cases of patients who are inpatient preoperatively (i.e., add-on cases)

Epstein RH, Dexter F. Anesth Analg 2015
Shi P et al. Anesth Analg 2016

Scenario 13 – Applying Bin Packing Principles

- Based on preceding bin packing results, both likely equally good choices
  - Balance of multiple factors including
    - Chance another long add-on case scheduled
    - Chance cancellation or delay, especially among cases of patients who are inpatient preoperatively (i.e., add-on cases)
  - ➢ Next lecture, we consider uncertainties and their influence on decision making, but for now an 0900 start reduces waiting

Format of Training

- As you "Record your answer," count the number of questions answered correctly
  - No credit for questions not answered
- At end of lecture, submit your count in poll

➢ Ready for Zoom!

- Evaluate how well you and your colleagues can predict results of management studies
  - All questions have 1 correct (best) answer

Dexter F et al. Anesthesiology 2004

Review – Summarize the Facts of the Talk

Make Decisions to be Down to Specified Numbers of ORs

Dexter F et al. Anesth Analg 2016

Make Decisions to be Down to Specified Numbers of ORs

- Suppose decisions on day of surgery based on specified numbers of ORs by hour of workday
  - Example would be 12 ORs from 7:00 AM to 2:59 PM, 4 ORs from 3:00 PM to 4:59 PM, 2 ORs from 5:00 PM to 6:59 PM, and then 1 OR

Make Decisions to be Down to Specified Numbers of ORs

- Suppose decisions on day of surgery based on specified numbers of ORs by hour of workday
  - Example would be 12 ORs from 7:00 AM to 2:59 PM, 4 ORs from 3:00 PM to 4:59 PM, 2 ORs from 5:00 PM to 6:59 PM, and then 1 OR
- ➢ Review all scenarios. For which can decision be made equally precisely based not on the ordered priorities but based on being down to specified numbers of ORs at time of day?
  - Different if surgical cases were tasks often stopped in middle and restarted next workday?

Lecture 2 – Impact of Uncertainties in Case Durations on Decision Making

Achieving On-Time Starts Through Information

- Throughout lectures, "> 1 surgeon in an OR on the same day" means 2 primary surgeons
  - Two sequential "lists" of cases
- In this lecture, you will learn how to model duration of a preceding list of cases in an OR
  - Often limited by having few historical data and large coefficient of variation of duration for combination of procedure(s) and surgeon
- Envision trying to achieve an on-time arrival of the 2nd surgeon in an OR that day

Achieving On-Time Starts Through Information

- Most common cause of late first case of the day starts is tardiness of the surgeon

Truong A et al. Can J Anesth 1996
Lapierre SD et al. Health Care Manag Sci 1999
Shelver SR, Winston L. AORN J 2001
Panni MK et al. Acta Anaesthesiol Scand 2013
Mathews L et al. J Neurosurg Anesthesiol 2015

Achieving On-Time Starts Through Information

- Contrast with being on-time for factory shift
  - Commute same route hundreds of times
    - Extensive personal experience
  - Motivated since pay is deducted proportional to tardiness if arrive > 15 minutes late

Dishon-Berkovits M, Berkovits R. Fractals 1997

Achieving On-Time Starts Through Information

- What % worker days with tardy arrival?
  - 0%
  - 3%
  - 10%
  - 13%
  - 20%
  - 23%
  - 30%

Achieving On-Time Starts Through Information

- What % worker days with tardy arrival?

  0%

  3%

  10%

  13% (9496 / 73,768 work days)

  20%

  23%

  30%

Achieving On-Time Starts Through Information

- Approximately half of the tardy arrivals are within how many minutes?

  5 minutes

  15 minutes (when pay reduced)

  30 minutes

  60 minutes

  120 minutes

Achieving On-Time Starts Through Information

- Approximately half of the tardy arrivals are within how many minutes?

  5 minutes

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  30 minutes

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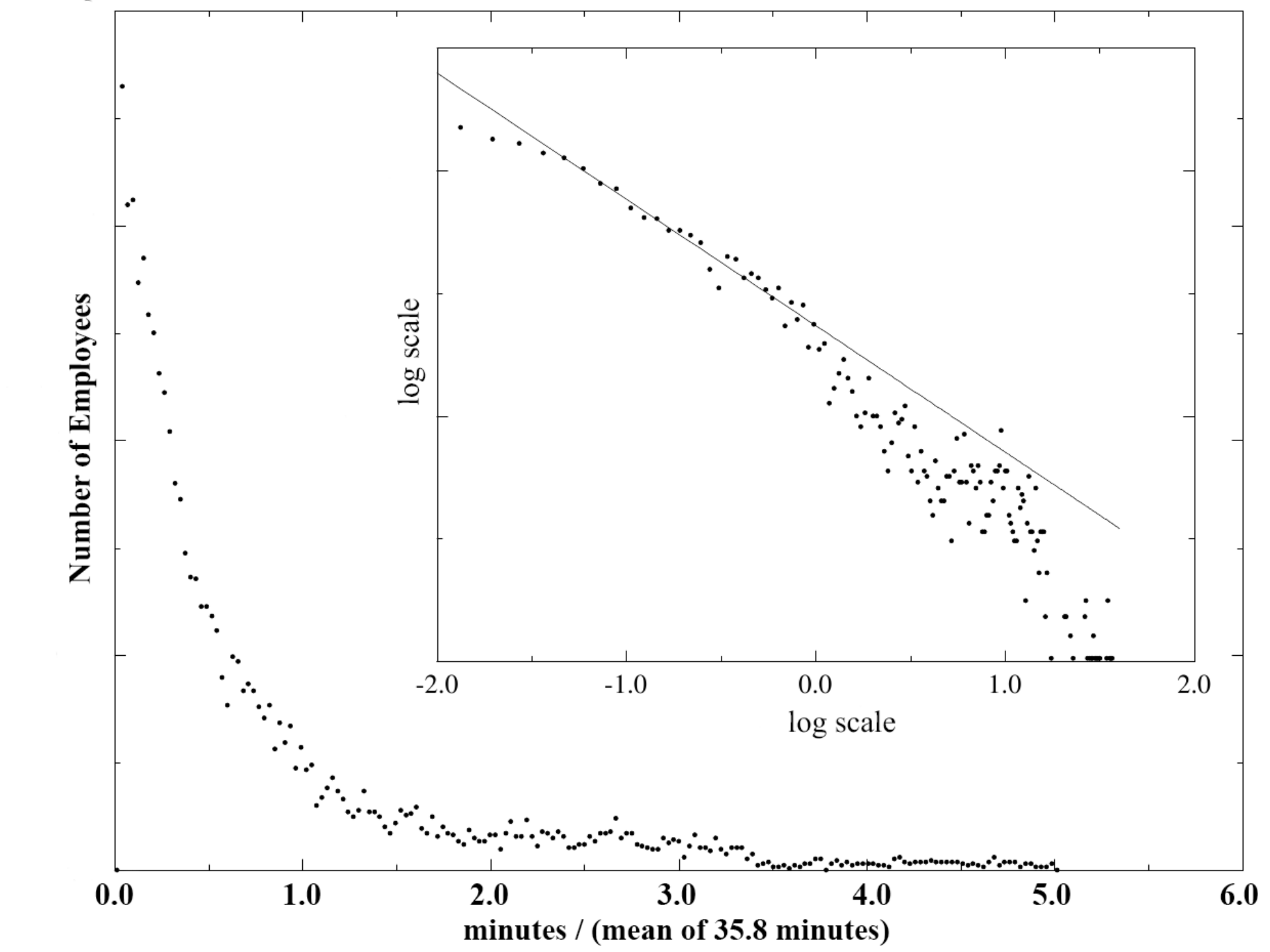
  120 minutes


Number of Employees
0.0
1.0
2.0
3.0
4.0
5.0
6.0
minutes / (mean of 35.8 minutes)
log scale
-2.0
-1.0
0.0
1.0
2.0
log scale

Achieving On-Time Starts Through Information

- Notification to patient care assistants 45 min before OR start time to go to selected intensive care unit (ICU) bed for preparation for transport
- Notification to anesthesia provider to be at the bedside 15 to 20 min ahead for patient communication handoff with the ICU RN
- Significantly reduced mean tardiness ($P < 0.0001$)

Brown MJ et al. J Healthc Qual 2015

Achieving On-Time Starts Through Information

- To improve consistency of decision-making among individuals, which of the following interventions likely is more important?
  - Provide everyone with historical data on all previous commutes to factory
  - Tell each person the time to leave for work

Dexter F et al. Anesth Analg 2007

Achieving On-Time Arrivals Through Information

- To improve consistency of decision-making among individuals, which of the following interventions likely is more important?
  - Provide everyone with historical data on all previous commutes to factory
  - Tell each person the time to leave for work

Moral About Data and Information Systems

- For operational decision-making, more data often will not change decision-making
- Need to learn whether the factor limiting the quality of the decision is lack of data or inconsistency in how the decision is made

How Would Complete Data on Driving Times be Used?

- If data on past 25 drives to the airport were collected by the management information system, what statistic likely would be provided to the decision-maker?

- What statistic would be ideal for driving time?

How Would Complete Data on Driving Times be Used?

- If data on past 25 drives to the airport were collected by the management information system, what statistic likely would be provided to the decision-maker?
  - Most hospital reports provide the means
- What statistic would be ideal for driving time?
  - Ideal statistic would relate to the percentage chance of being late in picking up visitor

General Lesson About Information Systems and Data

- *If* decision is best made relying on "shortest possible" (e.g., 5th percentile) or "longest possible" (e.g., 90th percentile)
- *And If* management information system reports provides mean of historical times
- *Then*, decision using the data will likely be worse than that based on experience

General Lesson About Information Systems and Data

- *If* decision is best made relying on "shortest possible" (e.g., 5th percentile) or "longest possible" (e.g., 90th percentile)
- *And If* management information system reports provides mean of historical times
- *Then*, decision using the data will likely be worse than that based on experience

Data driven operational decision making is often no better than non-data driven decisions

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
  - ➢ Case study on frustration with IT solution
- Applying methods based on mean duration
  - – Scheduling add-on cases, series of cases, moving cases, and assigning staff
- Sequencing cases to increase OR efficiency
- Upper prediction bounds to reduce waiting
- Lower prediction bounds to reduce waiting
- Time remaining in cases

Case Duration Prediction Accuracy Results

- To address complaints about surgeons waiting for other surgeons' late running cases, a hospital invests $1.2 million in a new OR information system that tracks case durations

  (Many years ago, why only $1.2 million)
- Six months after implementing the new information system, and using its calculated estimated durations, the mean absolute error is *less* accurate by a small amount (5 min)
- What five reasons can explain this finding?

Case Duration Prediction Accuracy Results

- **Patient and surgeon waiting does not relate to mean historical case duration**
- Should combine human & data information
- Mean is relatively insensitive to more data
- There is much process variability around the expected (mean) duration once the best method of prediction has been applied
- There are few historical data available on which to apply statistical methods

Case Duration Prediction Accuracy Results

- **Patient and surgeon waiting does not relate to mean historical case duration**
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- There are few historical data available on which to apply statistical methods

Should Combine Human & Data Information

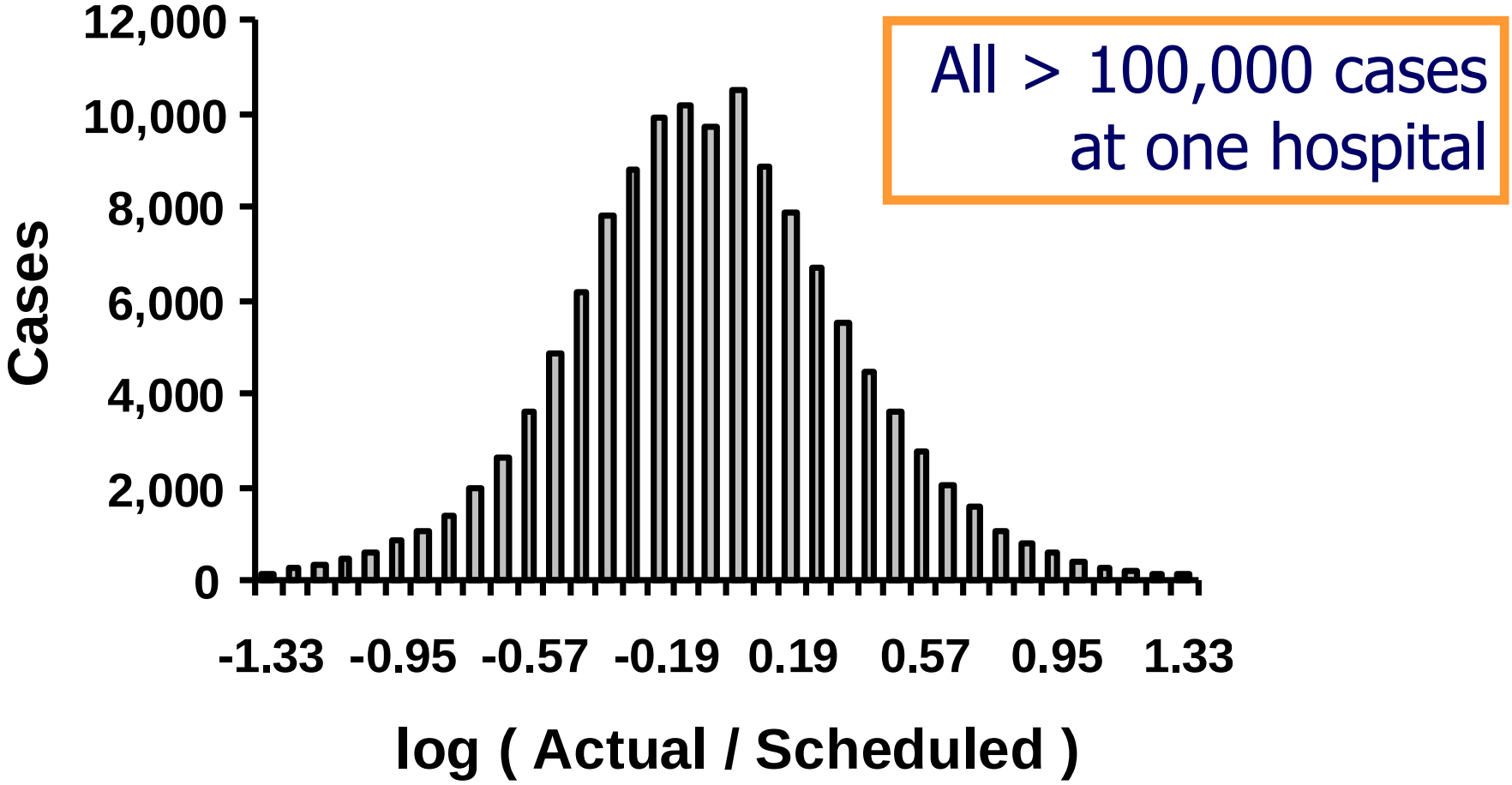
- Who will be most accurate at predicting how long it will take to drive to the airport?
  - Jim uses mean of previous times to drive
  - Jill guesses based on her experience
  - Betsy uses a two-step process:
    - 1st relies on the mean of all the times that she previously drove to the airport
    - 2nd revises the estimate up by 20%, because she will drive during rush hour, even though she usually does not

Should Combine Human & Data Information

- When surgeon is provided with her historical duration, and then updates that time based on her knowledge about the case (e.g., at intra-operative briefing), the accuracy is consistently equal to or better than:
  - surgeon only estimate
  - computer only estimate

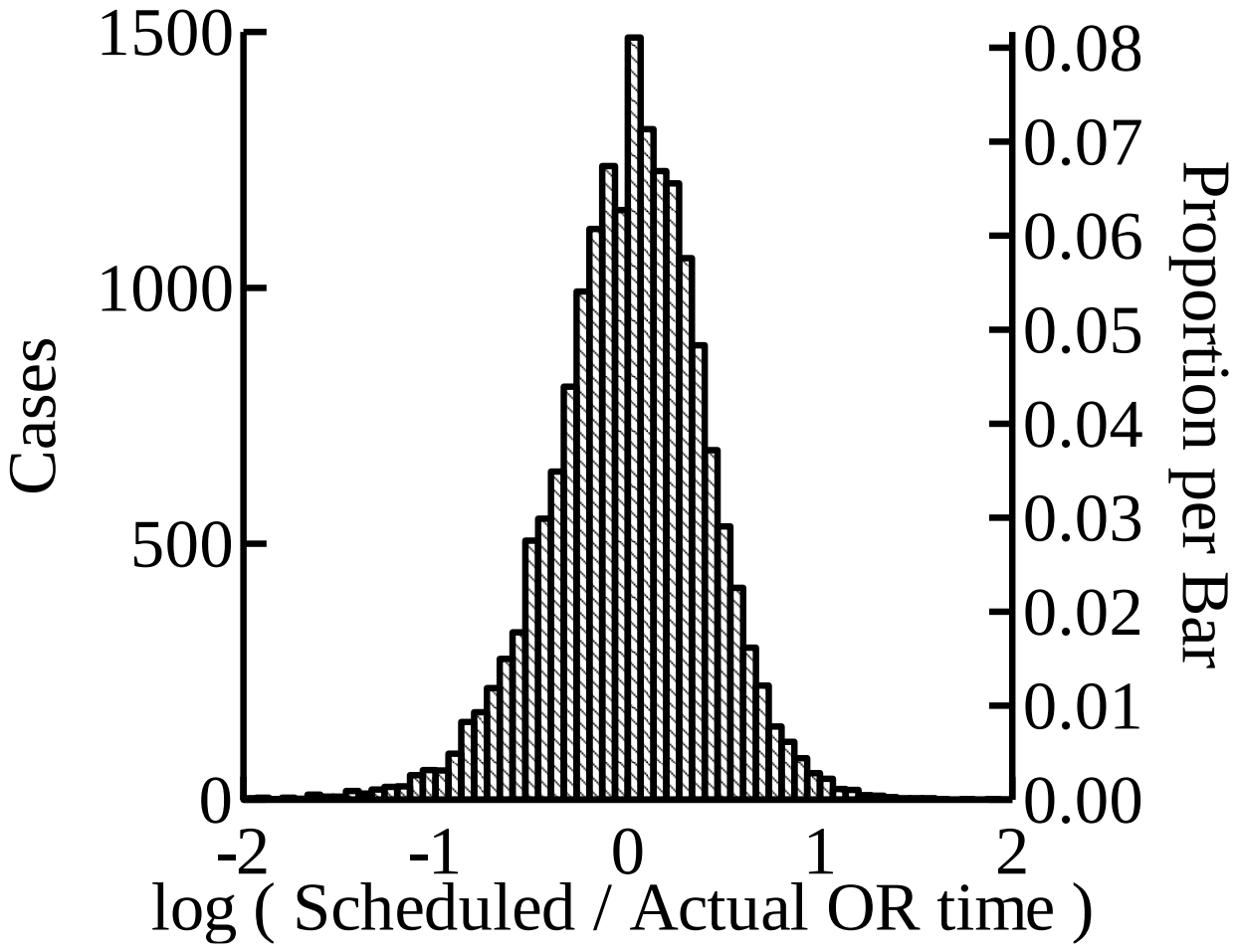
Wright IH et al. Anesthesiology 1996
Eijkemans MJC et al. Anesthesiology 2010
Dexter EU et al. Anesth Analg 2010
Dexter F et al. Anesth Analg 2013

Value of Estimated Duration From Surgeon



Dexter F et al. Anesth Analg 2009

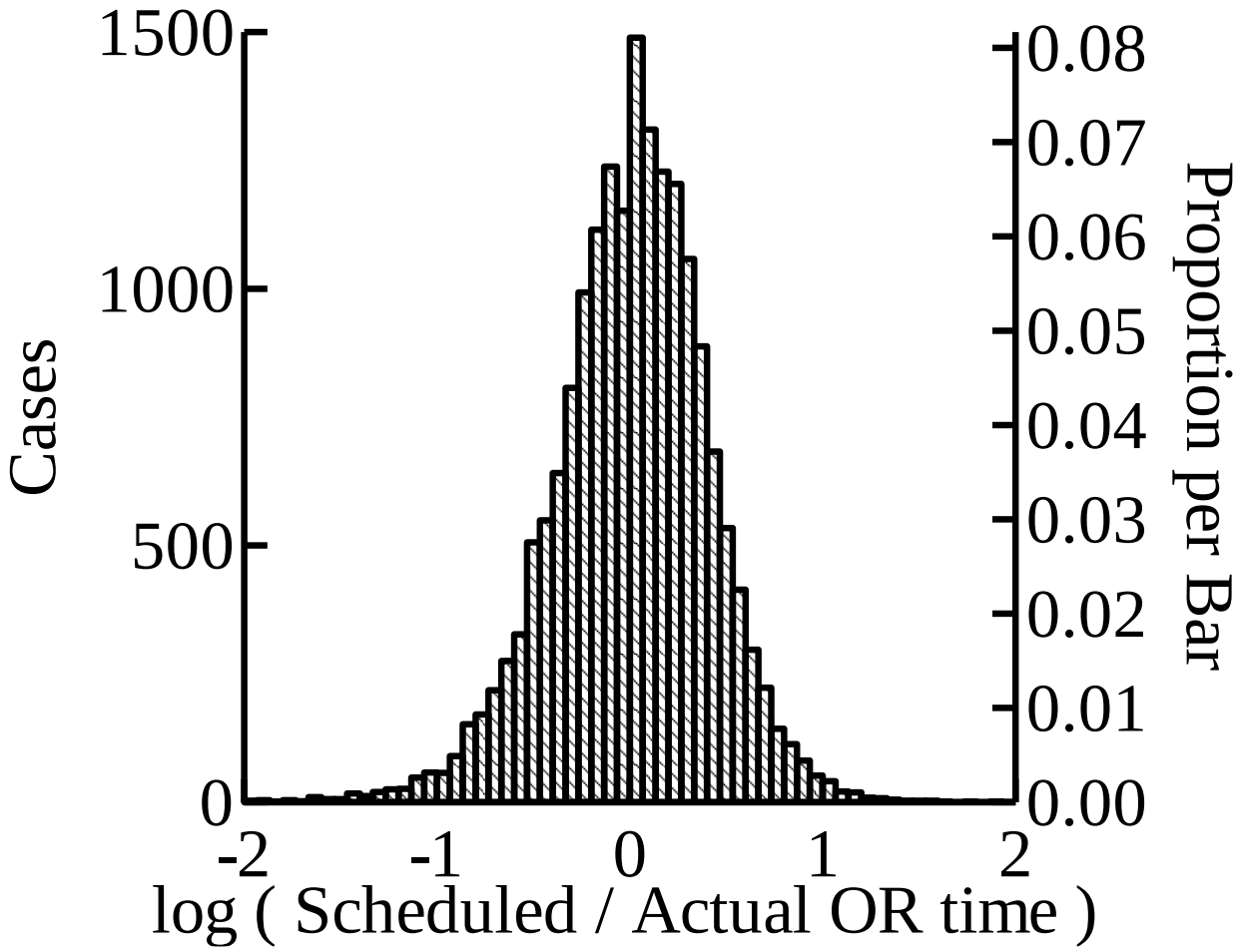
Value of Estimated Duration From Surgeon



18,000 cases with 0 or 1 historical data

Dexter F, Ledolter J. Anesthesiology 2005

Value of Estimated Duration From Surgeon



18,000 cases with 0 or 1 historical data

Dexter F, Ledolter J. Anesthesiology 2005

Value of Computer Estimate From Historical Data

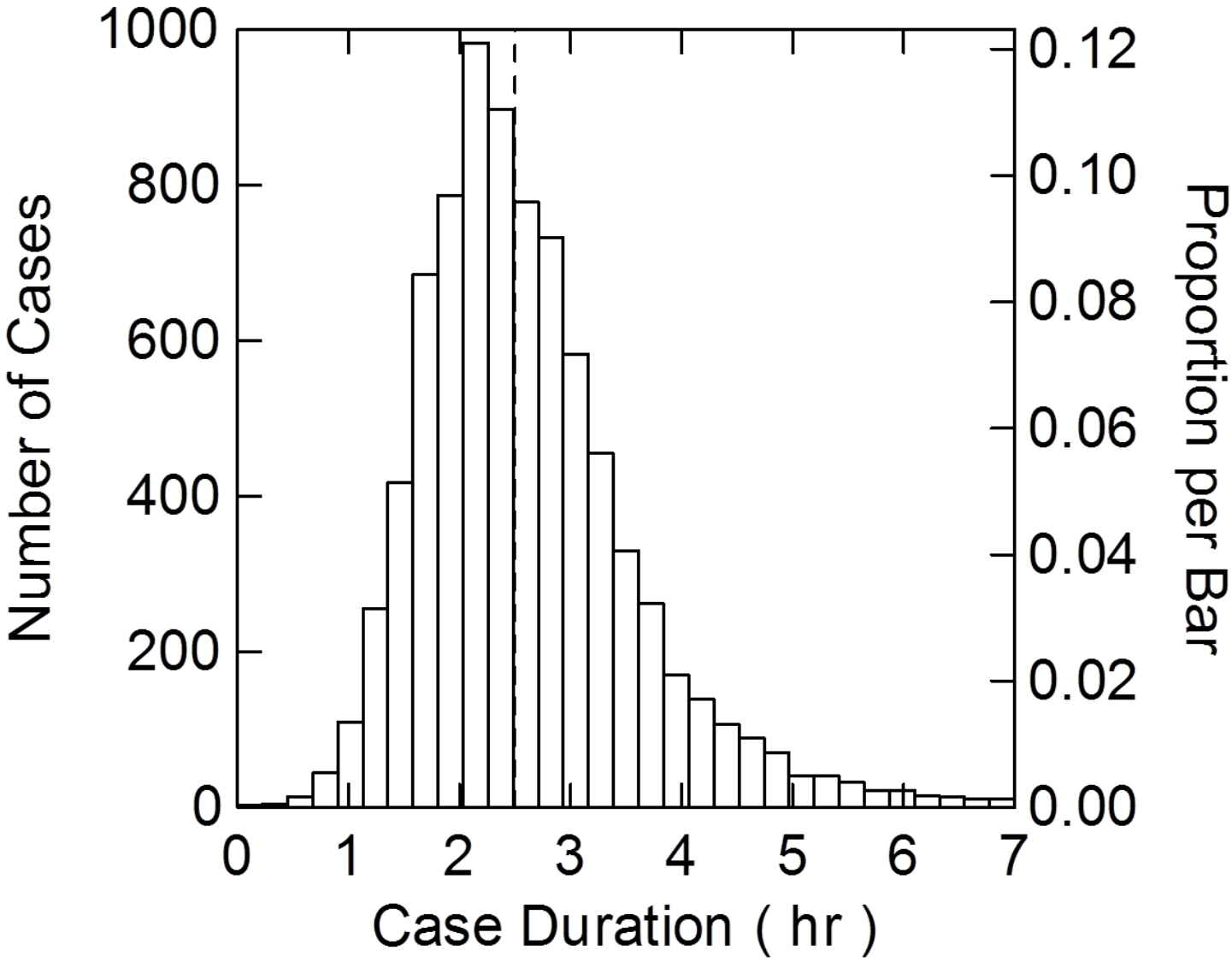
Value of Computer Estimate From Historical Data

- 4000 cases with estimated duration of 2.5 hr
  - Estimated value from surgeon or scheduler

Dexter F, Ledolter J. Anesthesiology 2005

Dexter F et al. J Clin Anesth 2007

Value of Computer Estimate From Historical Data



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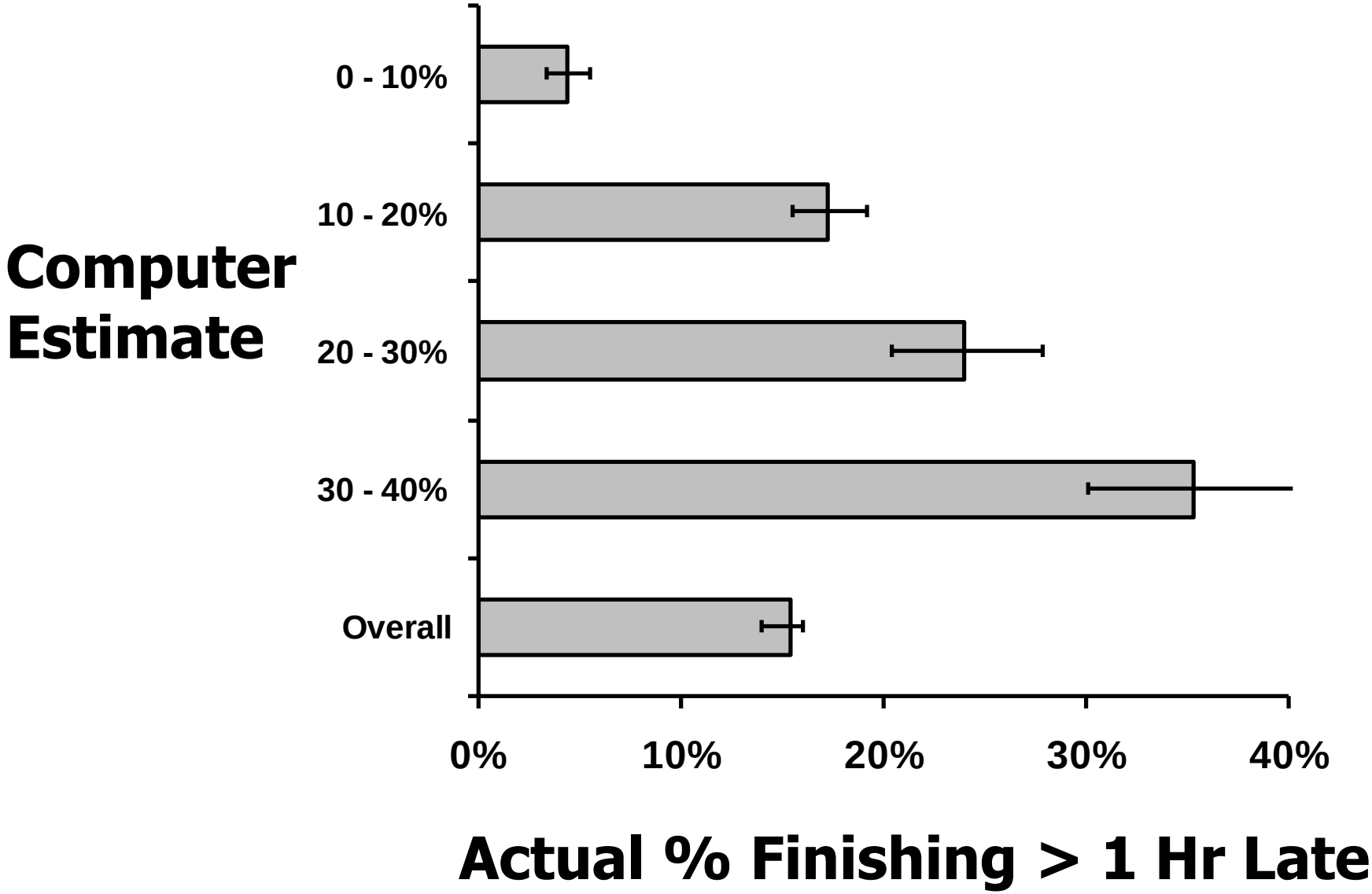

Case Duration Prediction Accuracy Results

- **Patient and surgeon waiting does not relate to mean historical case duration**
- Should combine human & data information
  - Mean is relatively insensitive to more data
- There is much process variability around the expected (mean) duration once the best method of prediction has been applied
- There are few historical data available on which to apply statistical methods

Mean is Relatively Insensitive to More Data

- Case durations listed sequentially for one surgeon performing total hip replacement

1) 3.62 hr
2) 2.77 hr
3) 4.38 hr
4) 4.00 hr
5) 3.15 hr
6) 3.42 hr
7) 4.38 hr
8) 3.33 hr
9) 3.77 hr

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9) 3.77 hr

I successively calculated mean as I added more historical data

Mean is Relatively Insensitive to More Data

- Case durations listed sequentially for one surgeon performing total hip replacement

1)	3.62 hr	3.62 hr
2)	2.77 hr	3.20 hr
3)	4.38 hr	3.59 hr
4)	4.00 hr	3.69 hr
5)	3.15 hr	3.58 hr
6)	3.42 hr	3.56 hr
7)	4.38 hr	3.67 hr
8)	3.33 hr	3.63 hr
9)	3.77 hr	3.65 hr

Final value for comparison

Mean is Relatively Insensitive to More Data

- Case durations listed sequentially for one surgeon performing total hip replacement

1)	3.62 hr	3.62 hr
2)	2.77 hr	3.20 hr
3)	4.38 hr	3.59 hr
4)	4.00 hr	3.69 hr
5)	3.15 hr	3.58 hr
6)	3.42 hr	3.56 hr
7)	4.38 hr	3.67 hr
8)	3.33 hr	3.63 hr
9)	3.77 hr	3.65 hr

Mean is Relatively Insensitive to More Data

- Incremental reduction in error in predicting mean case duration small once ≥ 3 previous cases of the same procedure(s) and surgeon
- Even if number of previous cases available to estimate case durations were increased from 1 to 39, the average tardiness would be reduced only by 2 min at a studied ambulatory surgery center and 4 min at a studied hospital

Zhou J et al. J Clin Anesth 1999

Dexter F et al. Anesth Analg 2013

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Large Process Variability About Expected (Mean) Duration

- Case durations listed sequentially for one surgeon performing total hip replacement

1)	3.62 hr	-0.03 hr
2)	2.77 hr	-0.88 hr
3)	4.38 hr	0.73 hr
4)	4.00 hr	0.35 hr
5)	3.15 hr	-0.40 hr
6)	3.42 hr	-0.23 hr
7)	4.38 hr	0.73 hr
8)	3.33 hr	-0.32 hr
9)	3.77 hr	0.12 hr

Difference from mean of 3.65 hr

Large Process Variability About Expected (Mean) Duration

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Results markedly underestimate the problem at a hospital surgical suite

Large Process Variability About Expected (Mean) Duration

- For total hip replacement, when scheduled procedure is total hip replacement, so will be the performed procedure

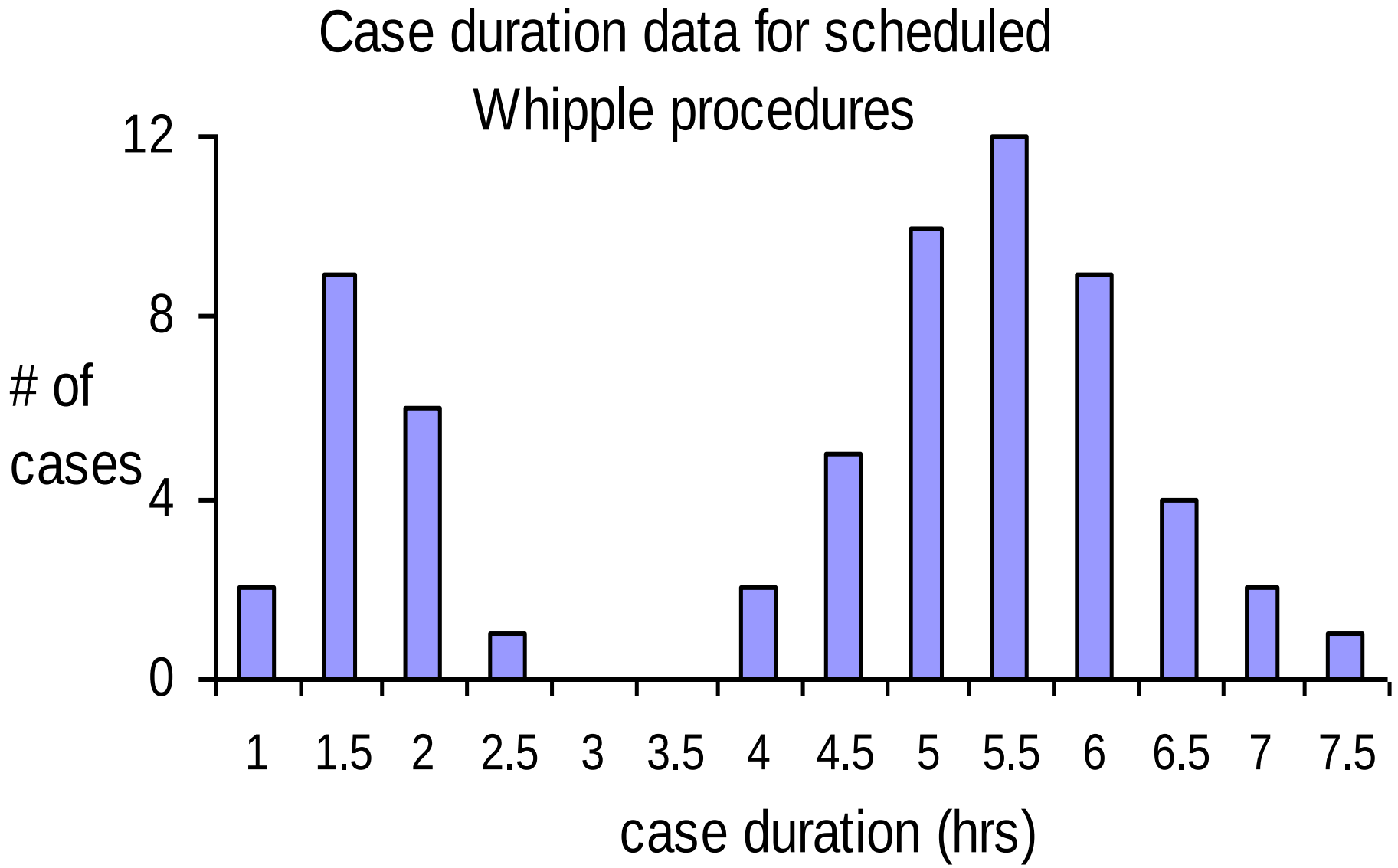
Large Process Variability About Expected (Mean) Duration

- For total hip replacement, when scheduled procedure is total hip replacement, so will be the performed procedure
  - For many cases, there are frequent differences between scheduled procedures and actual procedures

Dexter F et al. Anesth Analg 2010

Large Process Variability About Expected (Mean) Duration

- For total hip replacement, when scheduled procedure is total hip replacement, so will be the performed procedure
- For many cases, there are frequent differences between scheduled procedures and actual procedures
  - Cancer surgery
  - Major intra-abdominal procedures



Macario A. Anesth Analg 2009

Partial Solution to the Problem of Process Variability

- 6 hour is the mean case duration for the past ten Whipple procedures performed by Dr. Jones at Community General Hospital
- Dr. Jones expects his case tomorrow to be of average complexity
- Is 6 hours the expected (mean) duration of the next case?

Partial Solution to the Problem of Process Variability

- Take the mean of case durations for the past ten cases ***scheduled*** to be Whipple
  - Even include cases cancelled on the day of surgery before the patient enters the OR
- Doing this assures that the mean of historical durations is an unbiased estimator for the expected (mean) duration for future cases scheduled to be a Whipple procedure

Dexter F et al. Anesth Analg 2010

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Explain the Following Result

- SurgiServer OR information system provided estimated case durations using trimmed mean
  - Most recent cases (max 10) were taken of the same procedure performed by same surgeon
  - Shortest and longest durations were excluded
  - Mean was taken of the remaining eight cases
- Mean difference < 0.1 hr between estimates by sample mean and by trimmed mean
- Thinking about the equation, why was this true for most procedures?

Explain the Following Result

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  - Shortest and longest durations were excluded
  - Mean was taken of the remaining eight cases
- Mean difference < 0.1 hr between estimates by sample mean and by trimmed mean

➢ Most cases have fewer than 10 occurrences of the same procedure(s) by the same surgeon

Few Historical Data Available on Which to Apply Statistics

- Obsolete ICD-9-CM procedure coding system had 2,373 major therapeutic procedures
  - Typically performed in operating room
  - Penetrates or breaks the skin
  - Not percutaneous or endoscopic procedure
- Current ICD-10-PCS system has 49,730 major therapeutic procedures
  - Many very rare, but with combinations, even with 1 quarter of data, observe 49,548

O'Neill L et al. J Clin Anesth 2017

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O'Neill L et al. J Clin Anesth 2017

Few Historical Data Available on Which to Apply Statistics

- Characteristics of a hospital surgical suite
  - 11,579 cases → ***1.6 : 1.0***
  - 5,156 scheduled procedures and combinations of procedures based on CPT codes
  - 225 surgeons
  - 7,217 combinations of procedures & surgeon
- Characteristics of an outpatient surgical suite
  - 4,842 cases
  - 2,245 combinations of procedures & surgeon

Zhou J et al. J Clin Anesth 1999

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- Characteristics of an outpatient surgical suite
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  - 2,245 combinations of procedures & surgeon

2.2 : 1.0

Few Historical Data Available on Which to Apply Statistics

- Hospital surgical suite's one year of data
  - Previous cases of the same combination of scheduled procedure(s) and surgeons
  - *37%* of cases with *0* previous cases
  - 36% of cases with 1-5 previous cases
  - 12% of cases with > 19 previous cases

Zhou J et al. J Clin Anesth 1999

Few Historical Data Available on Which to Apply Statistics

- VA Medical Center in Pittsburgh compared test (2010) and historical (2006 to 2009) periods
- No historical data for the procedure

  20% of procedures and 5% of cases
- 0 or 1 occurrence in historical period

  36% of procedures and 10% of cases
- 0 to 9 occurrences in historical period

  75% of procedures and 39% of cases

Luangkesorn KL, Eren-Doğu ZF. J Statist Comput Simulation 2016

Few Historical Data Available on Which to Apply Statistics

- 36% of all cases performed per year in the US were of a procedure or combination of procedures performed on average once per facility per year

Dexter F, Macario A. Anesth Analg 2000

Review – Summarize the Facts of the Talk

Review – Summarize the Facts of the Talk

- What summary statistic relates to tardy starts?
- Why need human provided duration estimate?
  - What gain from the historical data?
- Need many data to estimate mean?
  - Additional sample size helps estimate what?
- Hospital surgical suite with 1 yr historical data
  - What % future cases with >9 prior cases of same combination surgeon and procedure(s)?
    - Good enough to classify by procedure(s)?

Summary of Lesson Learned

- If case durations were known precisely, for each case, only one estimate would be needed for its duration
- Since case durations are uncertain, one single number cannot be used for accurate decision-making
  - There is no: "***The*** case duration"

Summary of Lesson Learned

- If case durations were known precisely, for each case, only one estimate would be needed for its duration
- Since case durations are uncertain, one single number cannot be used for accurate decision-making
  - There is no: "***The*** case duration"

➢ Understanding the problem … to solutions

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
- Case study on frustration with IT solution
- ➢ Applying methods based on mean duration
  - Scheduling add-on cases, series of cases, moving cases, and assigning staff
- Sequencing cases to increase OR efficiency
- Upper prediction bounds to reduce waiting
- Lower prediction bounds to reduce waiting
- Time remaining in cases

Estimating Expected (Mean) Case Duration

- If $\geq$ 1 previous case with same surgeon, scheduled procedure(s) and anesthetic,
  - Use the mean duration of those prior cases
- If not, and $\geq$ 1 previous case with same surgeon and scheduled procedure(s),
  - Use the mean duration of those prior cases
- If not, and $\geq$ 1 previous case with same scheduled procedure(s), …
- If not, use the largest of the means of the individual component procedures, …

Estimating Expected (Mean) Case Duration

- Predict expected (mean) time to complete a series of cases in same OR on the same day
  - Use sum of the means for each case

Estimating Expected (Mean) Case Duration

- More than 20 other methods that have been studied with a variety of statistical properties
- None has performed better than simply using the mean of historical cases classified using as much information as possible

Dexter F et al. J Clin Monit 1999

Macario A, Dexter F. Anesth Analg 1999

Estimating Expected (Mean) Case Duration

- More than 20 other methods that have been studied with a variety of statistical properties
- None has performed better than simply using the mean of historical cases classified using as much information as possible
  - ➢ None better than just double checking surgeon's estimate manually, either

Dexter F, Ledolter J. Anesthesiology 2005

Dexter F et al. J Clin Anesth 2007

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
- Case study on frustration with IT solution
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Scheduling Add-on Cases Using Bin Packing Methods

- Methods from Lecture 1 are applied to case durations estimated by taking means of historical data as on preceding slides
- At ambulatory surgery center with mean case durations of 1.6 hr, case duration inaccuracy resulted in 1.0 min of over-utilized OR time per day *vs.* knowing case durations perfectly
- At hospital with mean case durations of 3.6 hr, excess 5.4 min of over-utilized OR time

Dexter F, Traub RD. Anesth Analg 2002

Explanation of Why Performance is so Good

- Staffing is planned from 7 AM to 3 PM
- OR 1 has two cases scheduled with estimated durations of 4 hr and 2.5 hr
- OR 2 has two cases scheduled with estimated durations of 2 hr and 2 hr
- Into which OR schedule another 2 hr case?

Dexter F et al. Anesthesiology 1999

Dexter F, Ledolter J. Anesthesiology 2005

Wang Z, Dexter F. Periop Care Oper Room Manag 2022

Explanation of Why Performance is so Good

- Staffing is planned from 7 AM to 3 PM
- OR 1 has two cases scheduled with estimated durations of 4 hr and 2.5 hr **6.5 hr**
- OR 2 has two cases scheduled with estimated durations of 2 hr and 2 hr **4.0 hr**
- Into which OR schedule another 2 hr case?

➢ In this (and most) real-world situations, inaccuracy in predicting case duration is unlikely to have changed the original management ***decision***

Implication of the Good Performance

- Negligible ROI from improved add-on case scheduling from methods to improve accuracy of case duration prediction
  - Cameras in the ORs
  - Real-time patient tracking systems
  - Graphical airport-style displays
  - More sophisticated statistical algorithms

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  - Cameras in the ORs
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  - Graphical airport-style displays
  - More sophisticated statistical algorithms

➢ Does this mean poor ROI from decision-support software to assist managers in scheduling add-on cases?

Implication of the Good Performance

- As considered in lecture 1, decision-support is needed to assist in how the expected (mean) durations are ***used*** in decision-making
- Benefit of information systems is not from improved case duration prediction, but in how the estimated case durations are ***used***

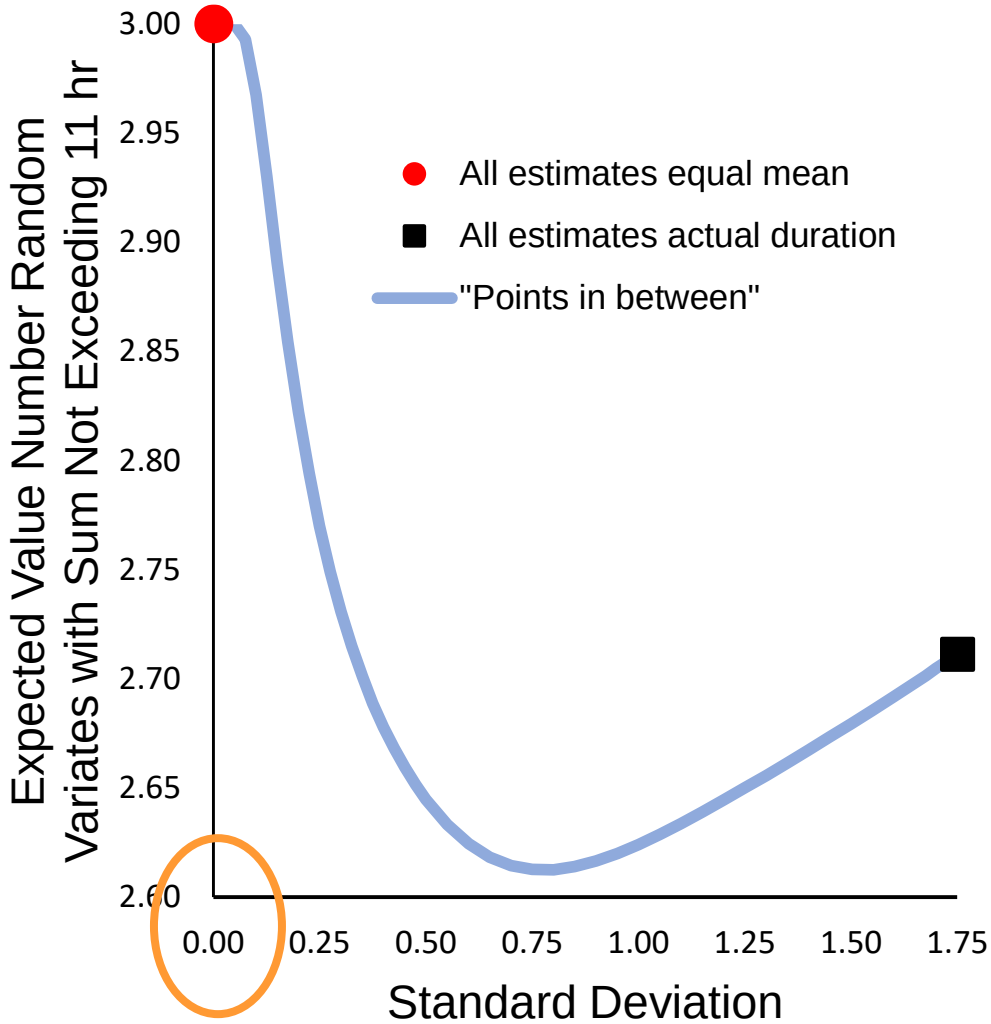
Same Conclusions for Series of Cases

- Staffing planned 1 OR from 7 AM to 6 PM
- Case durations mean 3.56 hr including turnover times, coefficient of variation 49%
- If estimate 3.56 hr for all cases, then schedule 3 cases per day, because 3 × 3.56 = 10.68 hr
  - Maximum unbiased absolute predictive error

Pandit JJ, Tavare A. Eur J Anaesthesiol 2011

Wang Z, Dexter F. Periop Care Oper Room Manag 2022

Same Conclusions for Series of Cases



Wang Z, Dexter F. Periop Care Oper Room Manag 2022

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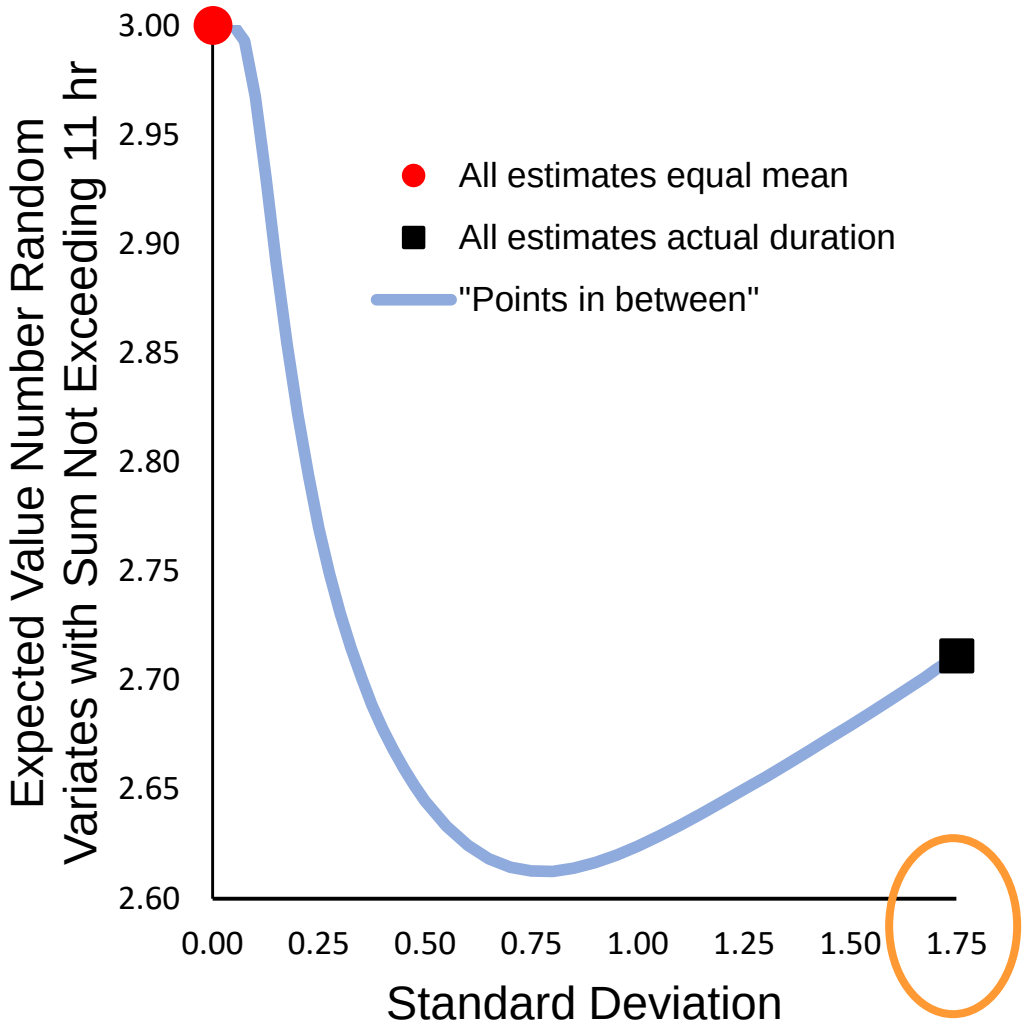
- If estimate 3.56 hr for all cases, then schedule 3 cases per day, because 3 × 3.56 = 10.68 hr
  - Maximum unbiased absolute predictive error
- ➢ If normally distributed random variates, how many cases scheduled on average?

Pandit JJ, Tavare A. Eur J Anaesthesiol 2011

Wang Z, Dexter F. Periop Care Oper Room Manag 2022

Same Conclusions for Series of Cases



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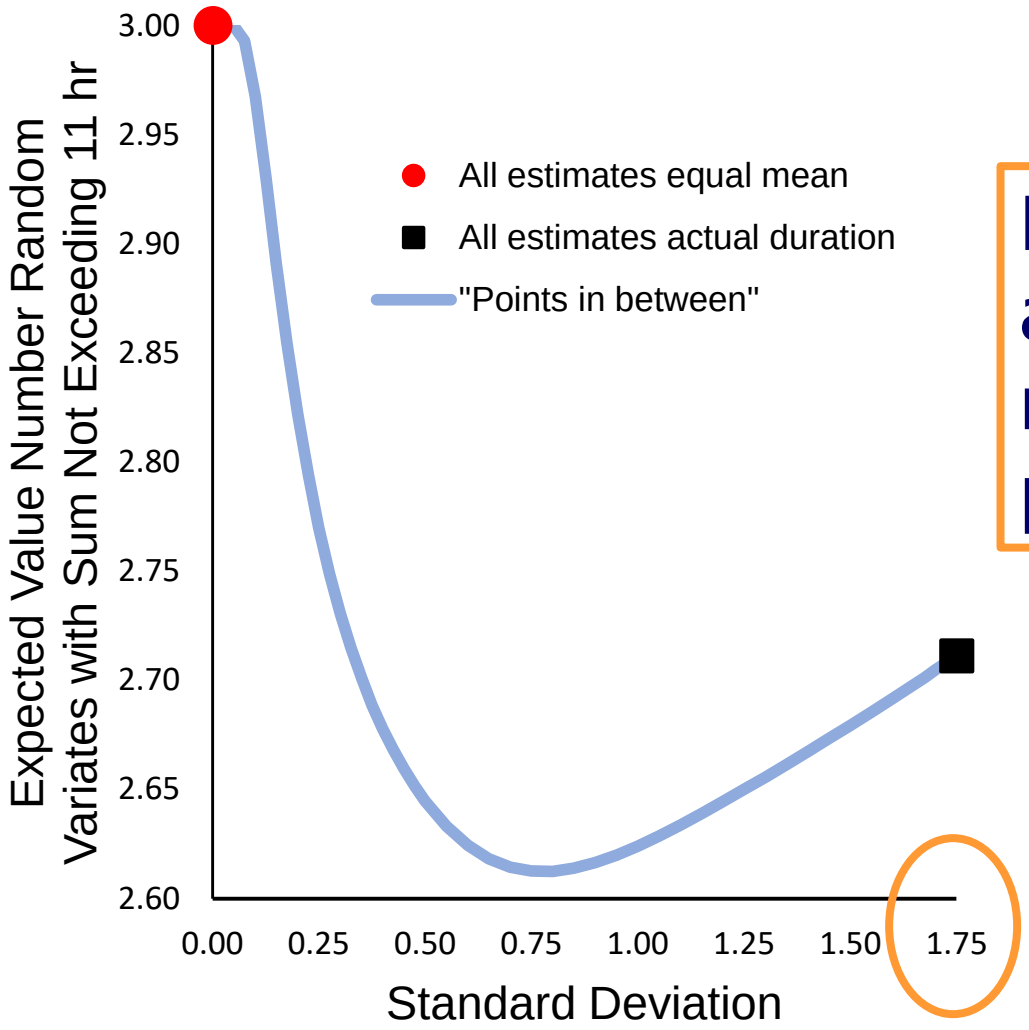

Reducing mean absolute predictive resulted in smaller productivity

Wang Z, Dexter F. Periop Care Oper Room Manag 2022

Realistic (non-intuitive) Discrete-Event Model

Resequencing day before and day of surgery	No		Yes	
	Baseline	Half	Baseline	Half
Absolute predictive error of case durations (hours)	0.60	0.30	0.60	0.30
Over-utilized time per room per day (hours)	0.27	0.11	0.19	0.08
Reduction in over-utilized time per room per day (minutes)		10		7
Cases per room per day	2.81	2.78	2.95	2.92
Decreases in cases per room per day (%)		1.0		1.0

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Decreases in cases per room per day (%)		1.0%		1.0%

Same Conclusions for Series of Cases

- Benefit of reducing the mean absolute predictive error is realized long-term by increasing staffing while maintaining same staff scheduling, increasing productivity
  - Not topic of current lecture, because calculation of staffing not done on the day of surgery or within a few days of surgery, but months ahead before choose staff scheduling

Wang Z, Dexter F. Periop Care Oper Room Manag 2022

Same Conclusions for Series of Cases

- Benefit of reducing the mean absolute predictive error is realized long-term by increasing staffing while maintaining same staff scheduling, increasing productivity
  - Not topic of current lecture, because calculation of staffing not done on the day of surgery or within a few days of surgery, but months ahead before choose staff scheduling
    - Service-specific operating room staffing
    - Economics of reducing turnover times
    - Reducing variability in anesthesia work hours by good decision-making in the scheduling office

Moving Cases

- Result is same as for add-on case scheduling
  - Benefit of information systems is not from improved case duration prediction, but in how the estimated case durations are used

Dexter F. Anesth Analg 2000

Dexter F et al. Anesthesiology 2004

Assigning Staff

- Suppose that OR 1 and OR 2 are still running at 5 PM, but all other ORs are finished
- One new OR team starts working at 5 PM
- Consider decision: which OR is relieved

Assigning Staff

- Estimate expected (mean) over-utilized OR time in OR1 and in OR 2
  - If mean historical duration of a case is 3 hr, and patient has been in an OR for 1 hr, then expected time remaining is slightly longer than 2 hr
- After make a preliminary decision, before relieving staff in planned OR, do a check to ensure that the OR to be relieved is not close to finishing
  - Walk to the OR and look in the window
  - Check anesthesia information system
  - Glance at a closed circuit camera
  - Phone call

Assigning Staff

- Excess over-utilized OR time from inaccuracy in predicting the time remaining is less than 1.4 min per OR per workday
  - Same reasons as for add-on case scheduling

Dexter F et al. Anesth Analg 1999

Assigning Staff

- Moral
  - These scenarios are ***not*** over-simplified
  - The world appears far more complex because:
    - Lack of focus on the decision options
    - Lack of a literature search

Wachtel RE, Dexter F. Anesth Analg 2013

Assigning Staff

- Moral
  - These scenarios are ***not*** over-simplified
  - The world appears far more complex because:
    - Lack of focus on the decision options
    - Lack of a literature search
      - ➢ Lack of knowledge of the vocabulary

Wachtel RE, Dexter F. Anesth Analg 2013

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
- Case study on frustration with IT solution
- Applying methods based on mean duration
  - Scheduling add-on cases, series of cases, moving cases, and assigning staff
- ➢ Sequencing cases to increase OR efficiency
- Upper prediction bounds to reduce waiting
- Lower prediction bounds to reduce waiting
- Time remaining in cases

Sequencing Cases to Increase OR Efficiency

- Dr. A has two cases today in OR 1
  - 2 hr case with a surgical microscope
  - 6 hr case without specialized equipment
- Dr. B one case today in OR 2
  - 3 hr case without specialized equipment
- Dr. B wants to add a 2nd case for today
  - 4 hr case with the surgical microscope
- Yet, other surgeons have also requested OR time for briefer cases

Sequencing Cases to Increase OR Efficiency

- Dr. A has two cases today in OR 1
  - 1st: 2 hr case with the microscope
  - 2nd: 6 hr case without microscope
- Dr. B would have two cases in OR 2
  - 1st: 3 hr case without the microscope
  - 2nd: 4 hr case with the microscope

Sequencing Cases to Increase OR Efficiency

- Dr. A has two cases today in OR 1
  - 1st: 2 hr case with the microscope
  - 2nd: 6 hr case without microscope
- Dr. B would have two cases in OR 2
  - 1st: 3 hr case without the microscope
  - 2nd: 4 hr case with the microscope

➢ OK if Dr. A finishes 1st case before Dr. B

➢ How judge whether uncertainty in estimate of case duration may affect decision?

➢ For which cases?

Sequencing Cases to Increase OR Efficiency

- Dr. A's 2 hr case with the surgical microscope
  - Mean, standard deviation, sample size
- Dr. B's 3 hr case without the microscope
  - Mean, standard deviation, sample size
- Standard deviations are used so that uncertainties in estimated mean durations are included in the calculations

Sequencing Cases to Increase OR Efficiency

- Dr. A's 2 hr case with the surgical microscope
  - Mean, standard deviation, sample size
- Dr. B's 3 hr case without the microscope
  - Mean, standard deviation, sample size
- Standard deviations are used so that uncertainties in estimated mean durations are included in the calculations
- ➢ From introductory statistics, what statistical test can be applied using this information?

Sequencing Cases to Increase OR Efficiency

- Determining probability that one case will last longer than another is similar to using ***Student's t-test*** to determine whether one mean exceeds another
  - Uncertainty is larger because two cases are being compared instead of two means
  - Probability estimated to accuracy < 1.5%

Dexter F, Traub RD. Anesth Analg 2000

Dexter F, Ledolter J. Anesthesiology 2005

Sequencing Cases to Increase OR Efficiency

- Consider two scenarios, both with data based on surgeon and scheduled procedure(s)
  - Dr. A's 2 hr case with the microscope
    - 1st scenario: Mean 2 hr, stdev 0.5 hr, N = 30
    - 2nd scenario: Mean 2 hr, stdev 1.0 hr, N = 2
  - Dr. B's 3 hr case without the microscope
    - 1st scenario: Mean 3 hr, stdev 0.8 hr, N = 40
    - 2nd scenario: Mean 3 hr, stdev 1.5 hr, N = 3
- Schedule Dr. B to follow himself with his add-on case for 1st, but not 2nd, scenario

Sequencing Cases to Increase OR Efficiency

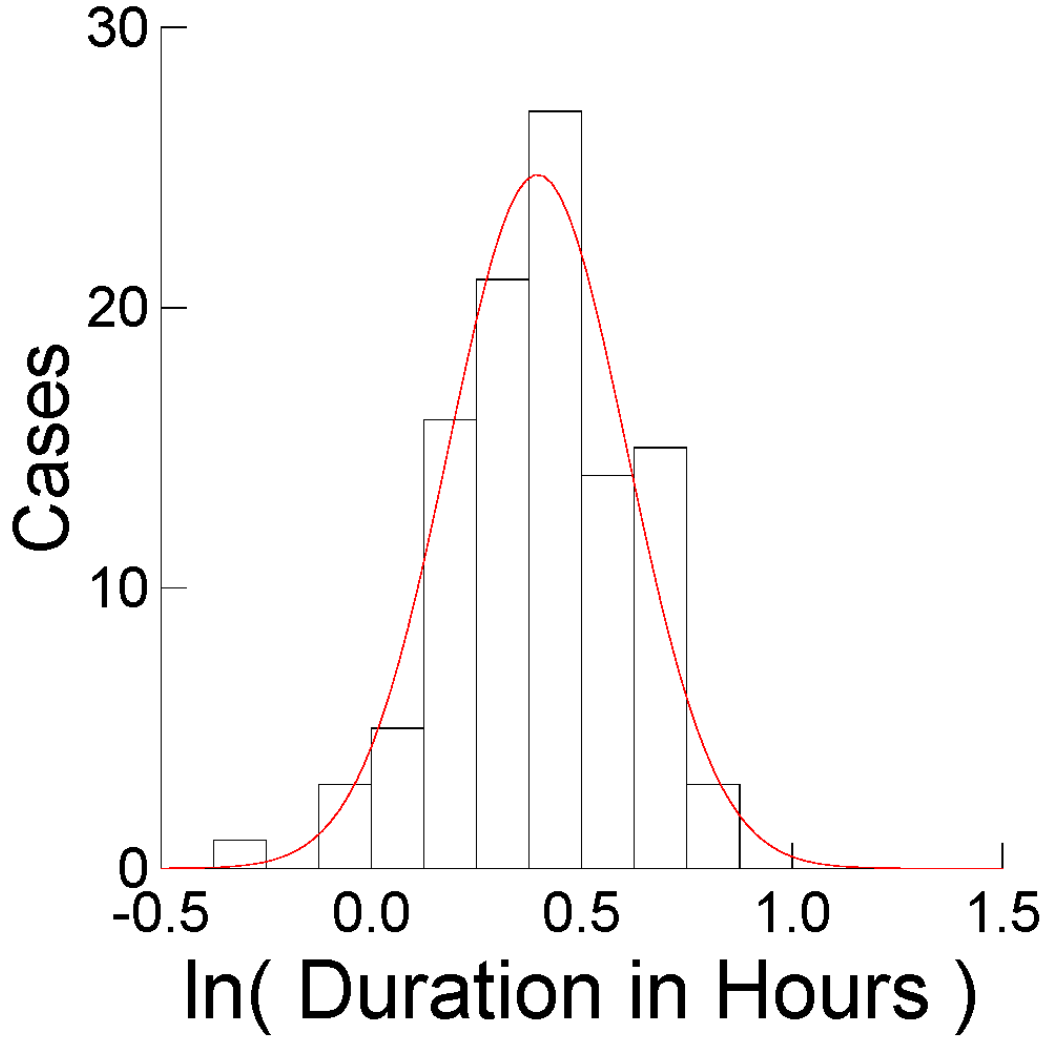
- For case sequencing decisions to reduce the impact of a constraint such as equipment, decision-support generally relies on analysis of relevant historical data
  - Do not need real-time data acquisition for this problem, just immediate access to analyzed historical data

Sequencing Cases to Increase OR Efficiency

- For case sequencing decisions to reduce the impact of a constraint such as equipment, decision-support generally relies on analysis of relevant historical data
  - Do not need real-time data acquisition for this problem, just immediate access to analyzed historical data
  - ➢ Do need statistical assumption that logarithms of case durations follow normal distributions
    - Basis for Student's t-test

Sequencing Cases to Increase OR Efficiency

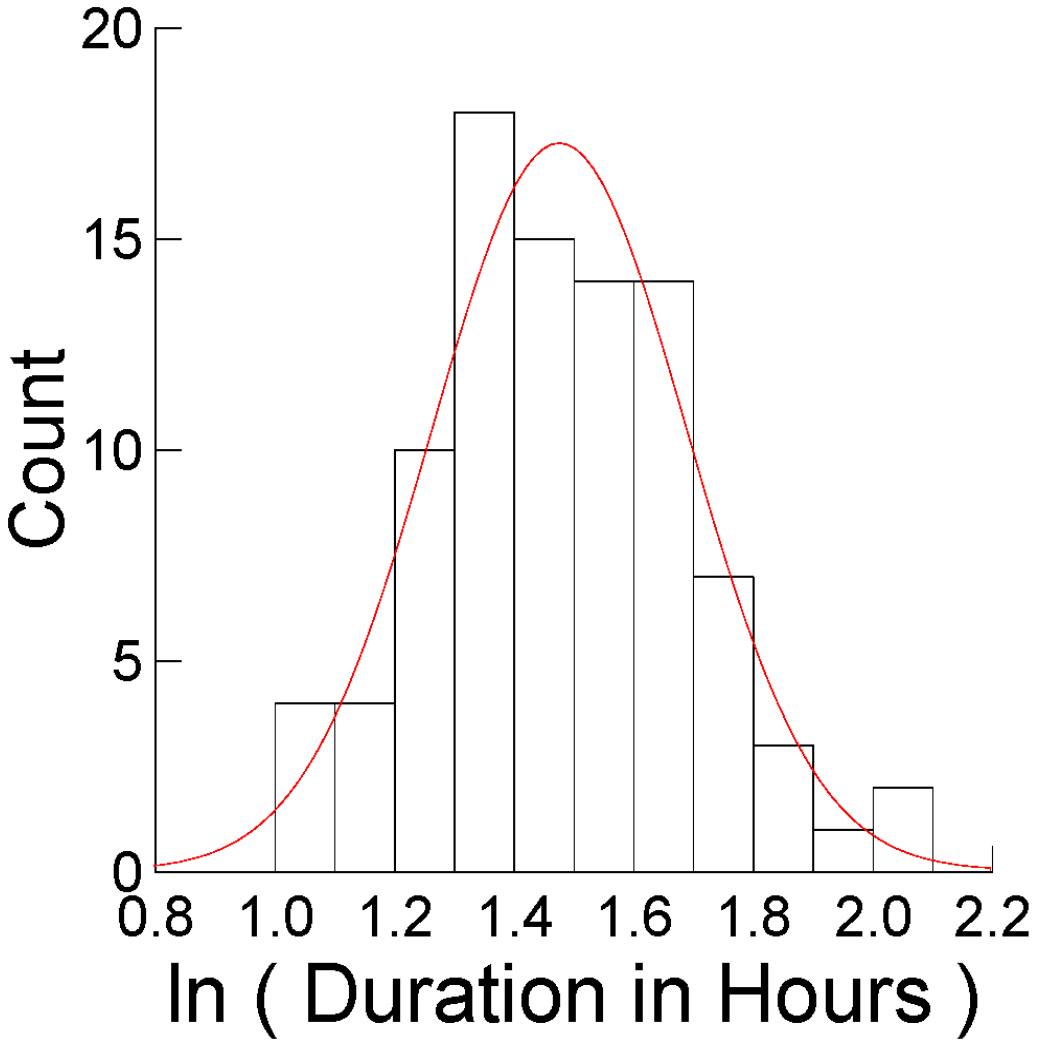
One surgeon's strabismus cases



Dexter F, Ledolter J. Anesthesiology 2005

Sequencing Cases to Increase OR Efficiency

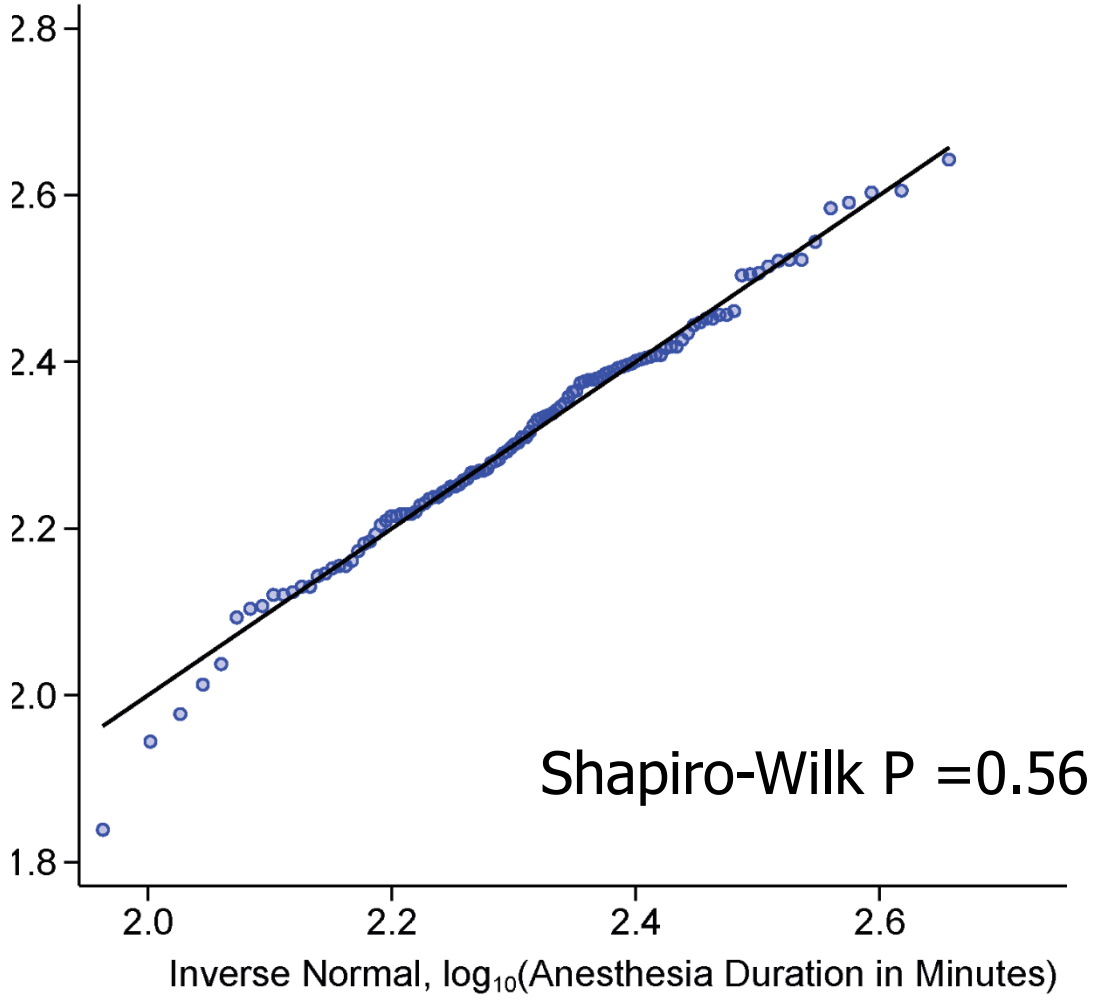
One facility's cerebral aneurysm clipping cases



Dexter F et al. Anesth Analg 2013

Sequencing Cases to Increase OR Efficiency

Dental anesthetics (dogs and cats)



Dexter F et al. Am J Vet Res 2024

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Prediction Bounds to Fill Holes in OR Schedule

- Definition
  - An upper prediction bound for the duration of a case is the value that will be exceeded by the next randomly selected case of the same type at the specified rate
  - There is a 10% chance that the duration of a case will be longer than its 90% prediction bound

Prediction Bounds to Fill Holes in OR Schedule

- Scenario showing why filling holes in the OR schedule reduces surgeon and patient waiting
  - Case 1 in OR 1 finishes unexpectedly at 10 AM
  - Case 2 in OR 1 cannot start until its scheduled time of 1 PM, because the surgeon is busy
  - There is a gap of 3 hr of available OR time
  - Dr. Holmes has an add-on case for today
    - Dr. Holmes is available to start until 12 noon
    - Dr. Holmes is then available tonight

Prediction Bounds to Fill Holes in OR Schedule

- The 90% upper prediction bound for the duration of Dr. Holmes' case is 2.3 hr
  - Case can be done in the 3 hr of open time with a low (< 10%) risk of causing an increase in over-utilized OR time from delaying the start of the case to follow
- Use of upper prediction bounds permits reduction in waiting times, while assuring a low risk of over-utilized OR time

Prediction Bounds to *Create Holes* in OR Schedule

- Four OR ambulatory surgery center has staffing 7 AM to 3 PM and no add-on cases
- In each of three of the four ORs, a surgeon has a list of cases for the day
- In OR 4, Dr. A has three cases scheduled from 7 AM to 10:30 AM followed by Dr. B with one case from 10:45 AM to 1 PM
- At 8 AM, Dr. A's first case has just started
- Updated end time for Dr. A's cases is 11:30

Prediction Bounds to Create Holes in OR Schedule

- Dr. B's patient can come later
- Dr. B would prefer to come later
- 90% upper prediction bound on the duration of Dr. B's case is 3 hr
- Dr. B can be given an updated start time of 12 noon without risking over-utilized OR time and thereby reduced OR efficiency

  12 noon = 3 PM – 3 hr

Prediction Bounds Statistical Methods

- Data required to calculate a prediction bound are mean, standard deviation, and sample size of historical case duration data
- Upper prediction bounds for duration of the next one case are accurate to within 1%

Zhou J, Dexter F. Anesthesiology 1998

Dexter F et al. Anesth Analg 2001

Dexter F, Ledolter J. Anesthesiology 2005

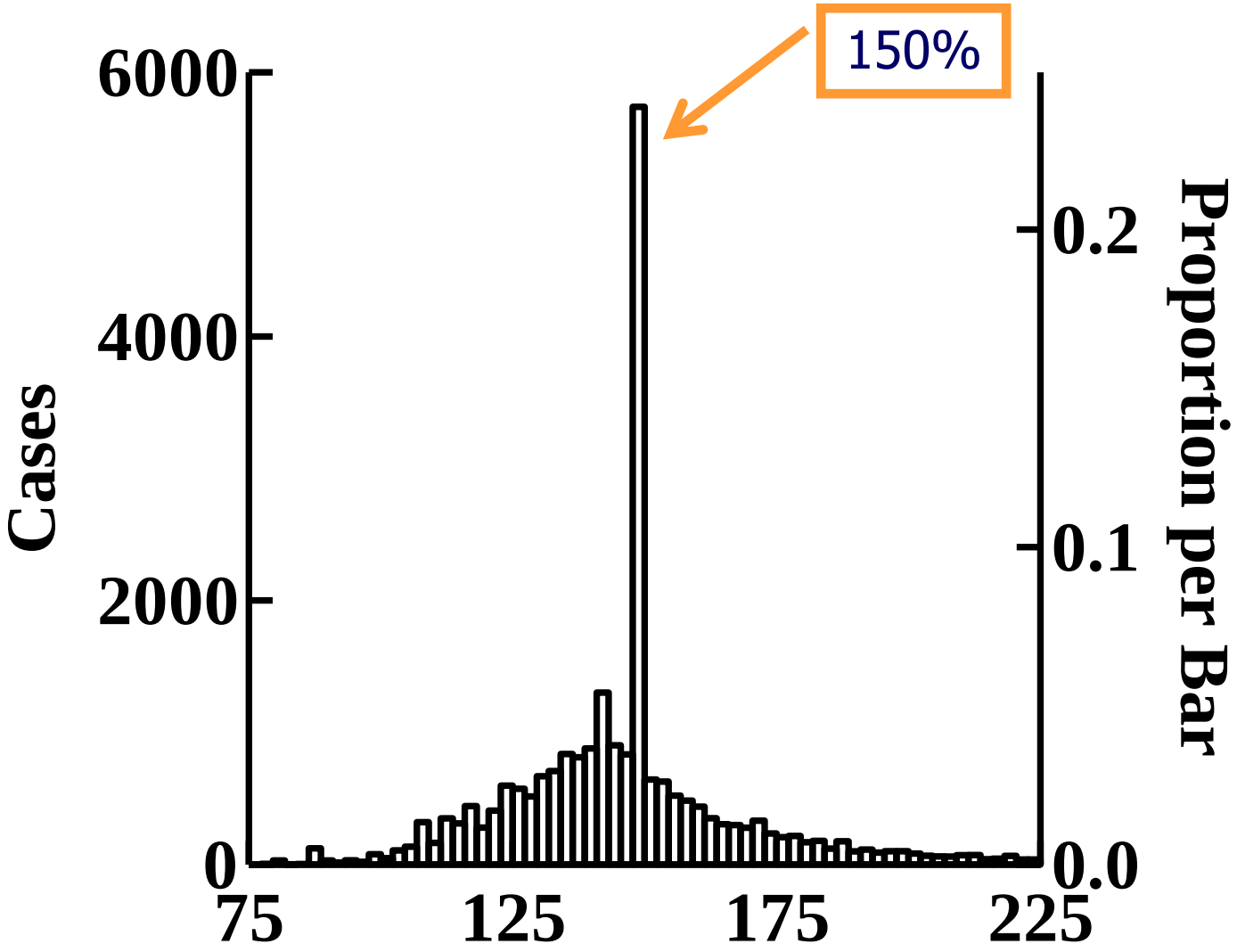
Tiwari V et al. Anesth Analg 2013

Prediction Bounds Statistical Methods

- Bayesian methods combine estimated duration and historical data
- If use only estimated duration to predict 90% upper prediction, ≅ 1.5 x estimated duration
  - Use this estimate for the many cases with no or few historical data available for procedure
- If more historical data available, use the data to have good upper prediction bound accuracy

Dexter F, Ledolter J. Anesthesiology 2005
Dexter F et al. Anesth Analg 2009

Prediction Bounds
Statistical Methods



Prediction Bounds to *Prevent Holes* in OR Schedule

- Patient's OR case started after radiological study (e.g., needle wire localization of tumor or stereotactic frame placement)
  - Choose radiology scheduled start time = scheduled start time of OR case minus 90% upper prediction bound for duration of the radiological procedure

Dexter F et al. Anesth Analg 2007

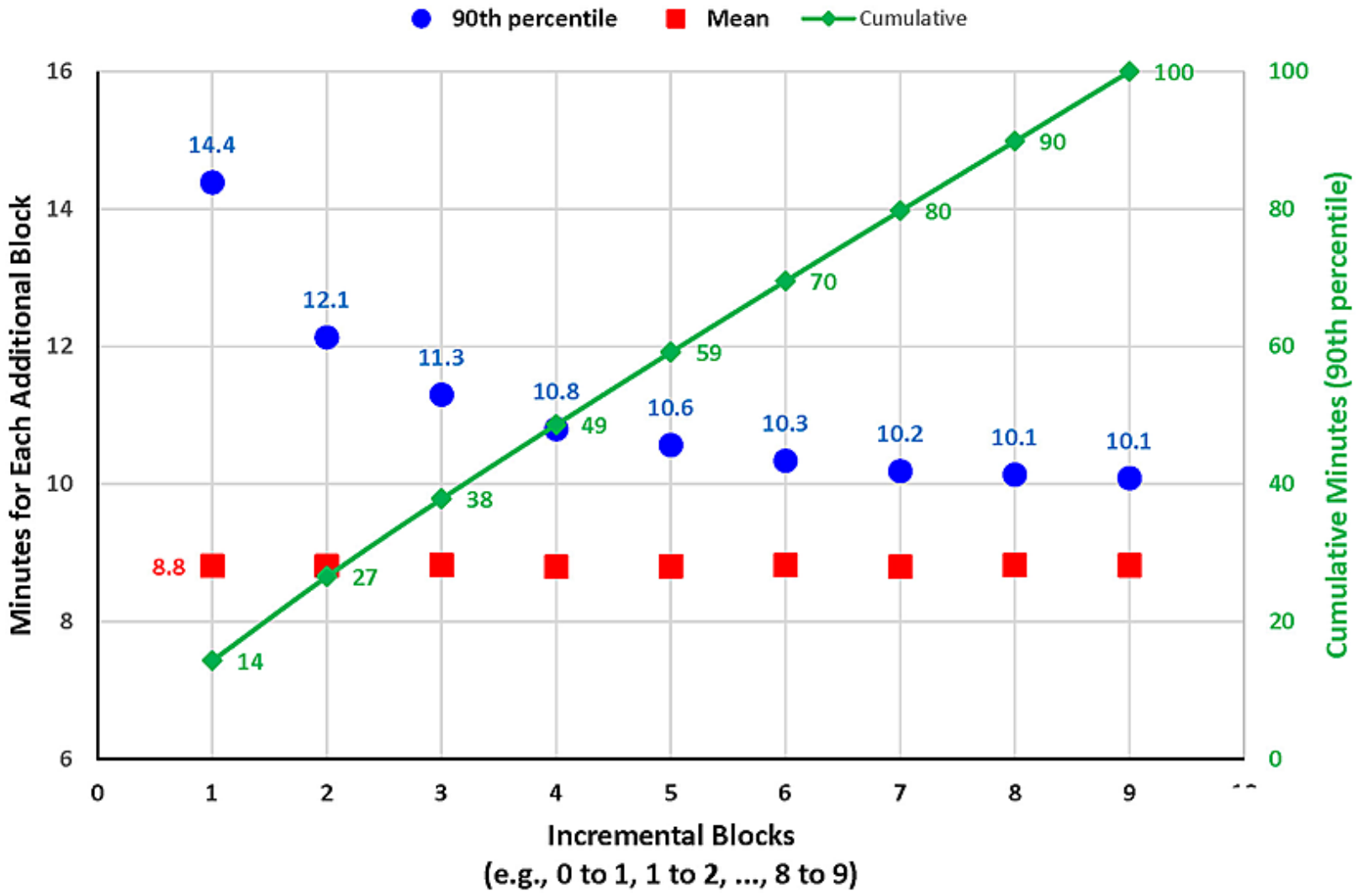
Meyer MA et al. Anesthesiology 2008

Prediction Bounds to Prevent Holes in OR Schedule

- Hospital uses holding area to place peripheral nerve blocks, acute pain catheters, arterial lines, and some central lines, thereby reducing time from OR entrance to incision
  - Plan patient time in holding area as 90% upper prediction bound for time to perform nursing assessment and then anesthesia procedures
    - Typically, one estimate for first case of the day start and another for subsequent cases

Epstein RH et al. Cureus 2021

Prediction Bounds to Prevent Holes in OR Schedule



Epstein RH et al. Cureus 2021

Prediction Bounds to Prevent Holes in OR Schedule

- For these non-surgical prediction bounds, statistical methods are different
  - Not using data just from your hospital
- Example: times to complete nerve blocks
  - Poor fits to normal, two-parameter log-normal, gamma, and Weibull distributions
  - Used Monte-Carlo simulation, sampling with replacement from the 1000's of observations

Dexter F et al. Anesth Analg 2007

Epstein RH et al. Cureus 2021

Review – Summarize the Facts of the Talk

When Apply Mean and When Apply Upper Prediction Bound?

- Scheduling an add-on case
- Sequencing cases to increase OR efficiency
- Creating gap between cases
- Deciding whether to fill a gap with lunch break or an add-on case

When Apply Mean and When Apply Upper Prediction Bound?

"If I use maximum, or 90% upper bound, to schedule an OR, my surgeons may complain that they're prevented from scheduling as many cases into their blocks of time. Alternatively, I might end up with a significant amount of underutilized time. Are these concerns legitimate?"

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
- Case study on frustration with IT solution
- Applying methods based on mean duration
  - Scheduling add-on cases, series of cases, moving cases, and assigning staff
- Sequencing cases to increase OR efficiency
- Upper prediction bounds to reduce waiting
- ➢ Lower prediction bounds to reduce waiting
- Time remaining in cases

Lower Prediction Bounds for When Patients are Ready

- Definition
  - There is 5% chance that duration of a case will be briefer than its 5% prediction bound
- Accuracy
  - The 5% lower prediction bounds calculated based on scheduled procedure(s) are accurate to within 0.3%

Dexter F, Traub RD. Anesthesiology 2000

Dexter F, Ledolter J. Anesthesiology 2005

Lower Prediction Bounds for When Patients are Ready

- If all patients ready before the OR is ready for them, patient waiting times would be long
- If all patients were ready just when their cases were scheduled to start, there would be marked under (causing over) utilized time
- Choice of when patients are ready is same as specifying the relative cost of patients' waiting time compared to cost of the staffs' idle time

Weiss IIE Transactions 1990

5% Prediction Bounds for When Patients are Ready

- P < 0.05 is common balance in medicine
  - Patients would arrive early enough that they wait 95% of time because OR is not ready, while staff wait 5% of time with empty ORs
- Median annual compensation in US of patients is 5% of sums of compensations for one patient, anesthesiologist, general surgeon, FTE housekeeper, and two nurses
- Measured actual % of occurrences ORs waited for patients at a hospital without a policy: 5%

Dexter F, Traub RD. Anesthesiology 2000
Wachtel RE, Dexter F. Anesth Analg 2007

Lower Prediction Bounds – Why Not Just An Hour or Two Early?

- Lower prediction bounds cannot be estimated accurately by using the expected (mean) duration and subtracting a safety factor
- At a hospital, patient being ready 2 hr before scheduled start of his/her case end yielded overall risk of OR staff waiting for patient of 5%
  - Among patients with a preceding case longer than 3.5 hr, the risk that the staff would wait for the patient was 14.3%

Dexter F, Traub RD. Anesthesiology 2000

Lower Prediction Bounds – Why Not Just An Hour or Two Early?

- If a case has an expected (mean) duration of 1.5 hr, its 5% to 90% bounds can be 1.0 hr (≅ 1/3rd less) to 2.0 hr (≅ 1/3rd more)
  - Appropriate safety factor would be 0.5 hr
- If a case has an expected (mean) duration of 6.0 hr, its 5% to 90% bounds can be 4.0 hr (≅ 1/3rd less) to 8.0 hr (≅ 1/3rd more)
  - Appropriate safety factor would be 2.0 hr
- Need to use the lower prediction bounds

Lower Prediction Bounds Information Systems

- Information system can provide value by …
  - Promptly communicating to decision-makers that there is a decision to be made
    - When patient calls or to call patients scheduled to have surgery later in the day
  - Providing immediate access to results of analysis of relevant historical data to assist them in making a quality decision

Lower Prediction Bounds Implementation

- Challenge in implementation is compensation for preceding case cancellation in same OR, moving of cases, rescheduling, etc.

Wachtel RE, Dexter F. Anesth Analg 2007

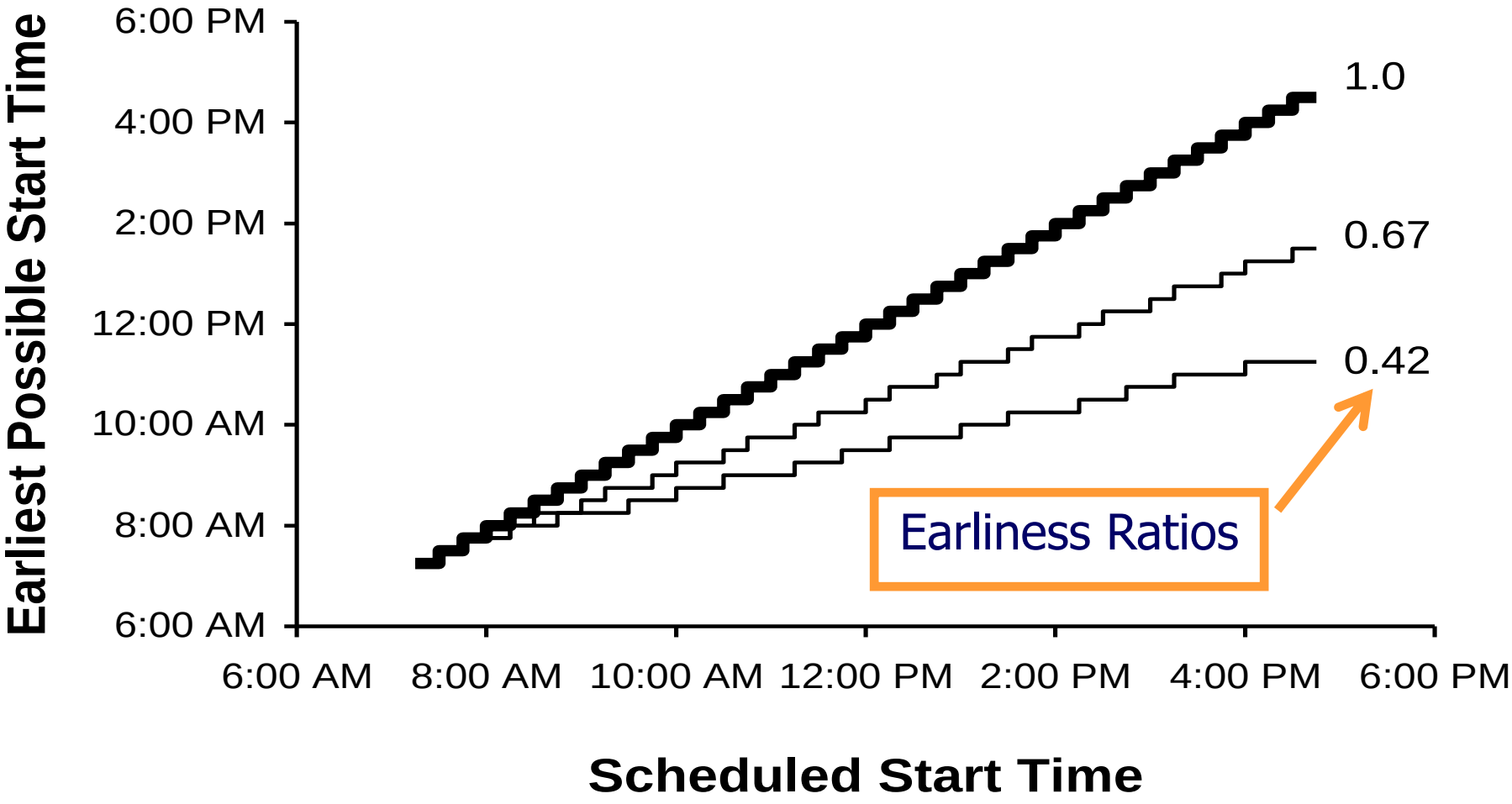
Smallman B, Dexter F. Anesth Analg 2010

Lower Prediction Bounds Implementation

- Challenge in implementation is compensation for preceding case cancellation in same OR, moving of cases, rescheduling, etc.

$$Earliness\ Ratio = \frac{\text{Actual Start Time} - (\text{Start of Workday} + 30\ \text{min})}{\text{Scheduled Start Time} - (\text{Start of Workday} + 30\ \text{min})}$$

Lower Prediction Bounds Implementation



Lower Prediction Bounds Implementation

N historical cases to calculate prediction bound	19	59	99	199
Percent of Cases with the N for Suite/Service/Day of Week Combination	98 ± 0.1%	98 ± 0.1%	94 ± 0.1%	80 ± 0.2%
Out-of-Bounds Rate for Combinations with >99 Cases	4.9 ± 0.1%	5.0 ± 0.1%	5.1 ± 0.2%	4.9 ± 0.2%
Mean Patient Wait for Combinations with >99 Cases	2 hr 4 min	1 hr 53 min	1 hr 51 min	1 hr 50 min
Coefficient of Variation of Lower Prediction Bounds	0.45 ± 0.01	0.23 ± 0.01	0.17 ± 0.01	0.10 ± 0.01

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Use 199 if have 199, 99 if have 99, 59 if have 59, ...

Service = 2 physicians

Day of Week = the physician

Table 1. Patient Ready, Arrival, and NPO Times Calculated Empirically from Scheduled Start Times and Displayed on Paper at Scheduler's Desks

Scheduled start time	Physician 1			Physician 2		
	Ready time	Arrival time	NPO liquids	Ready time	Arrival time	NPO liquids
9:00	8:50	8:20	5:50	8:55	8:25	5:55
9:15	9:00	8:30	6:00	9:05	8:35	6:05
9:30	9:10	8:40	6:10	9:20	8:50	6:20
9:45	9:20	8:50	6:20	9:35	9:05	6:35
10:00	9:30	9:00	6:30	9:45	9:15	6:45
10:15	9:40	9:10	6:40	10:00	9:30	7:00
10:30	9:50	9:20	6:50	10:10	9:40	7:10
10:45	10:00	9:30	7:00	10:25	9:55	7:25
11:00	10:10	9:40	7:10	10:40	10:10	7:40
11:15	10:20	9:50	7:20	10:50	10:20	7:50
11:30	10:30	10:00	7:30	11:05	10:35	8:05
11:45	10:40	10:10	7:40	11:15	10:45	8:15
12:00	10:50	10:20	7:50	11:30	11:00	8:30
12:15	11:00	10:30	8:00	11:45	11:15	8:45
12:30	11:10	10:40	8:10	11:55	11:25	8:55
12:45	11:20	10:50	8:20	12:10	11:40	9:10
13:00	11:30	11:00	8:30	12:20	11:50	9:20
13:15	11:40	11:10	8:40	12:35	12:05	9:35
13:30	11:50	11:20	8:50	12:50	12:20	9:50
13:45	12:00	11:30	9:00	13:00	12:30	10:00
14:00	12:10	11:40	9:10	13:15	12:45	10:15

Smallman B, Dexter F. Anesth Analg 2010

Topics Covered in Lecture 2

- Achieving on-time arrivals through information
- Case study on frustration with IT solution
- Applying methods based on mean duration
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Time Remaining in Cases – Hypothetical Example

Hours	Probability
1	10%
2	45%
3	25%
4	15%
5	5%

Time Remaining in Cases – Hypothetical Example

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Hr into Case	Expected (Mean) Time Remaining
0	2.6 hr
1	1.8 hr
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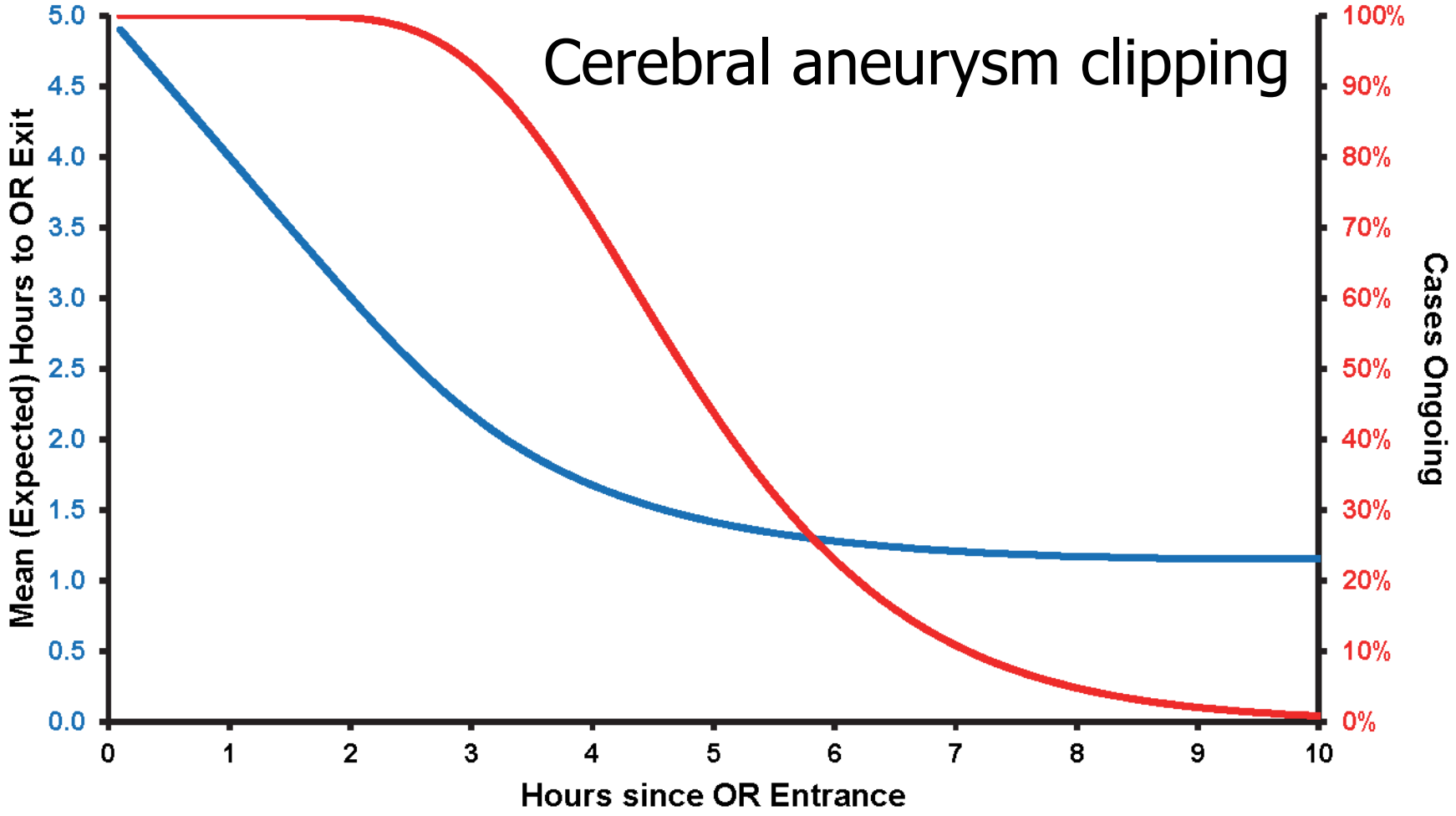
➢ After 2.6 hr, there is not 0 hr expected time remaining!

Non-Preemptive Tasks of Uncertain Durations



Dexter F et al. and Tiwari V et al. Anesth Analg 2013

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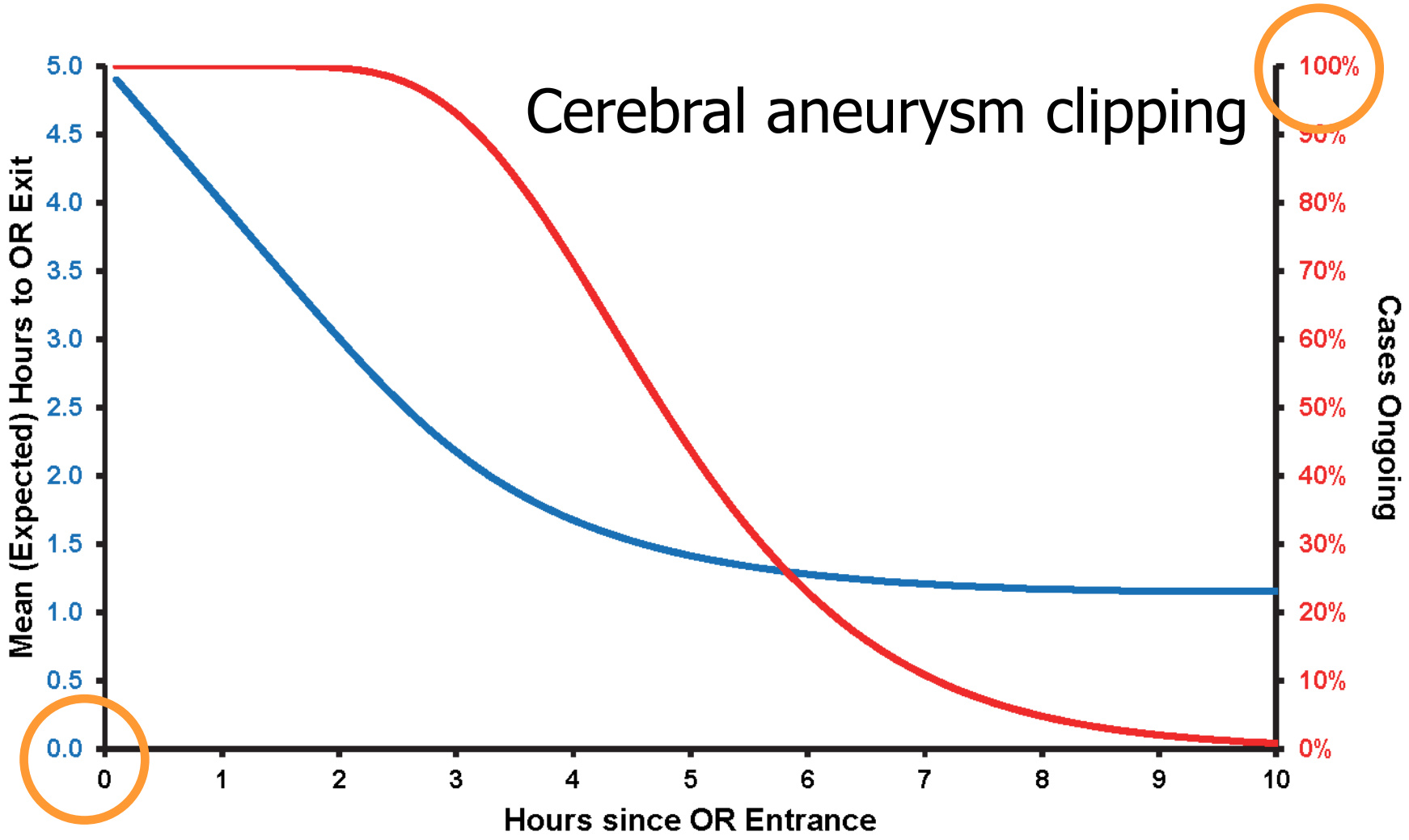

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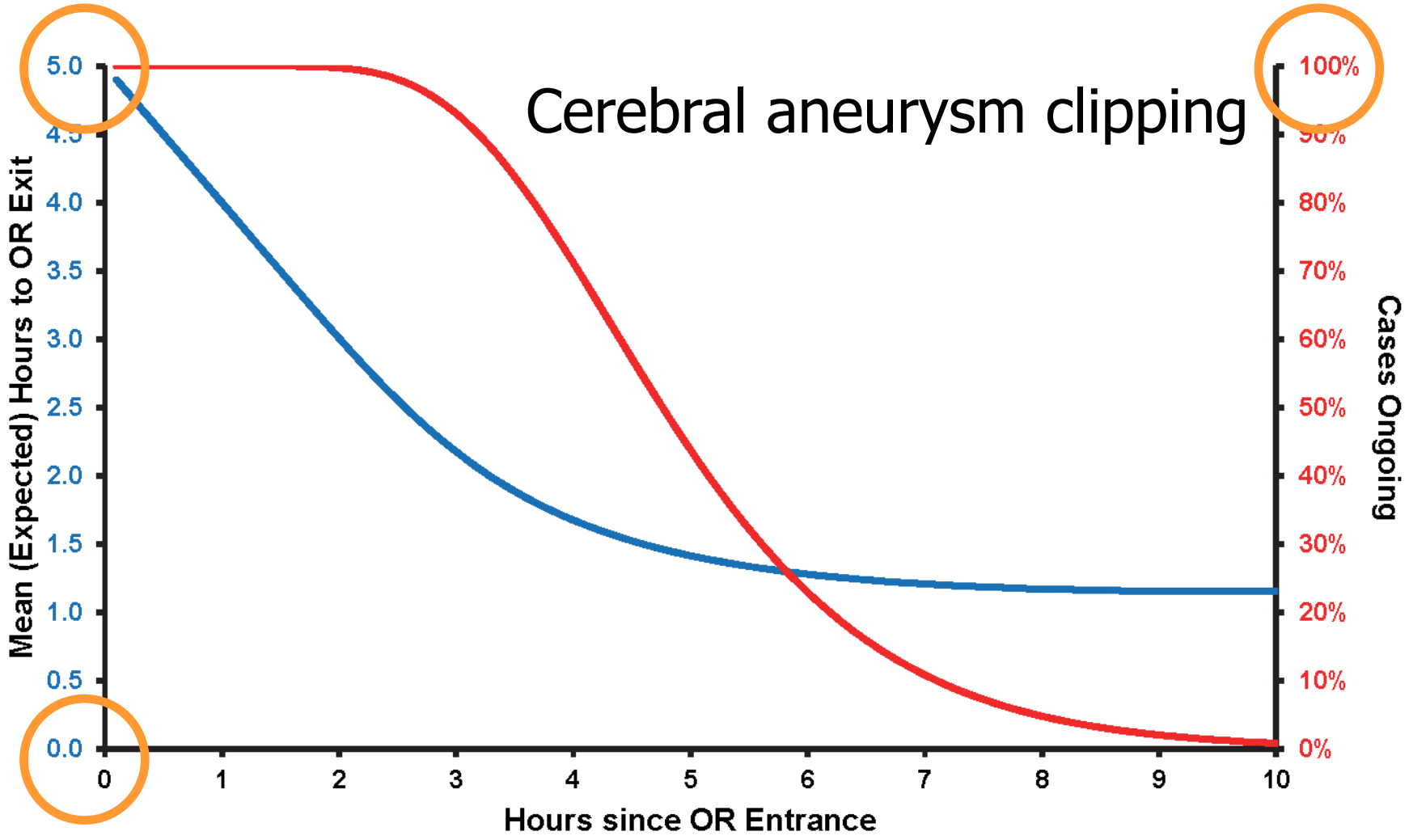

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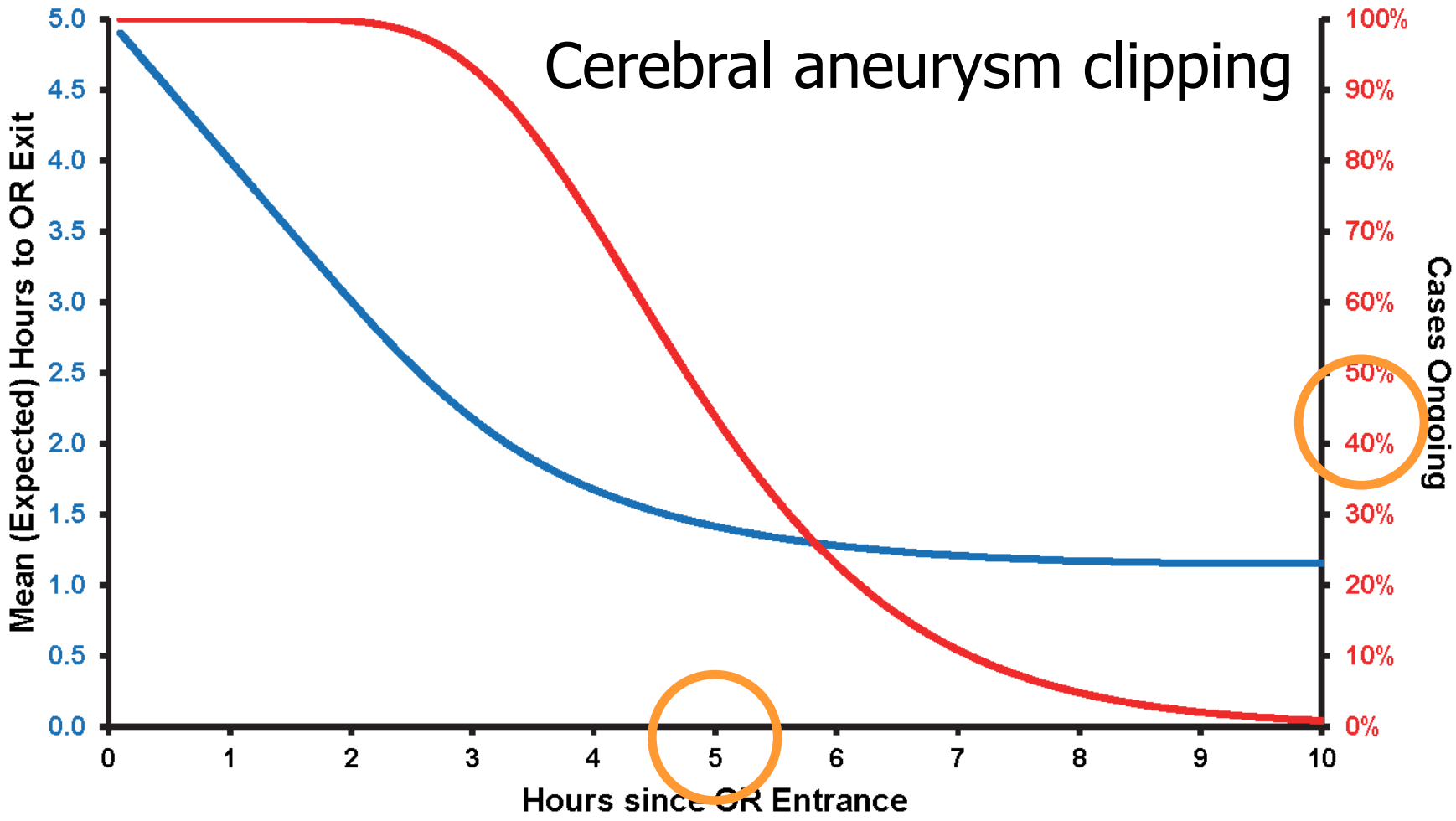

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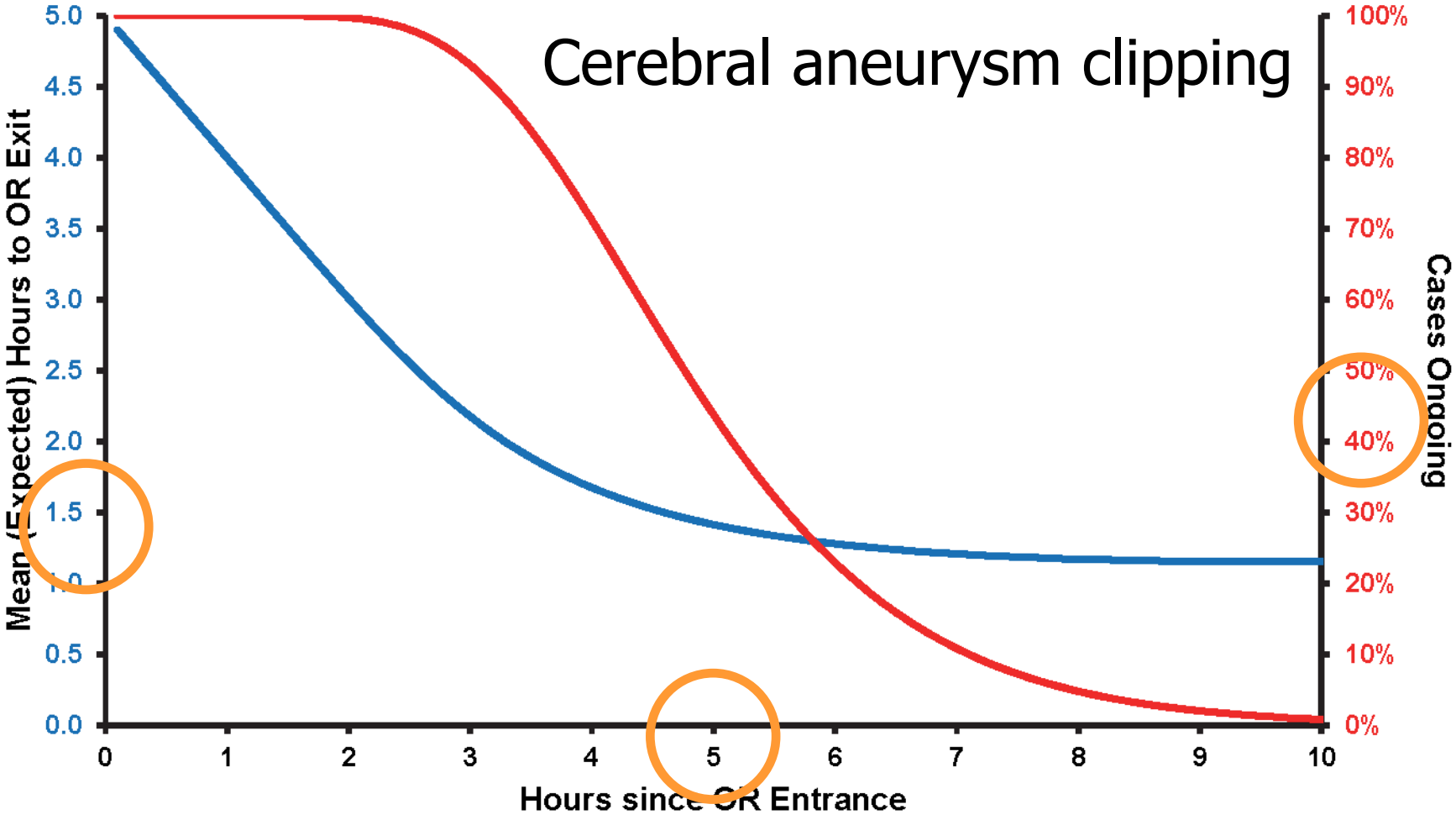

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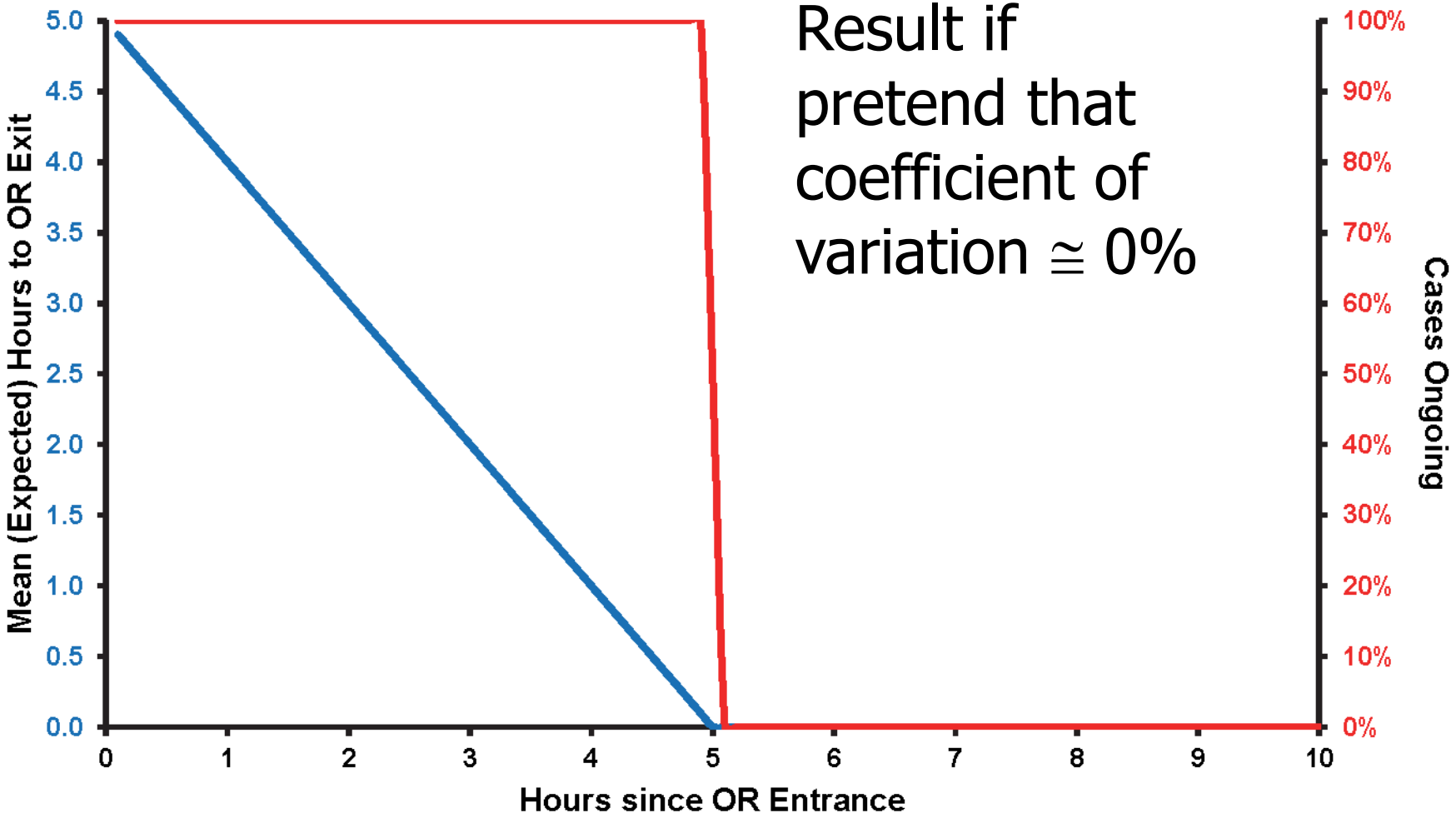

Result if pretend that coefficient of variation ≅ 0%

Non-Preemptive Tasks of Uncertain Durations

Other Examples
2 Procedures Estimated ≅ 1 Hr

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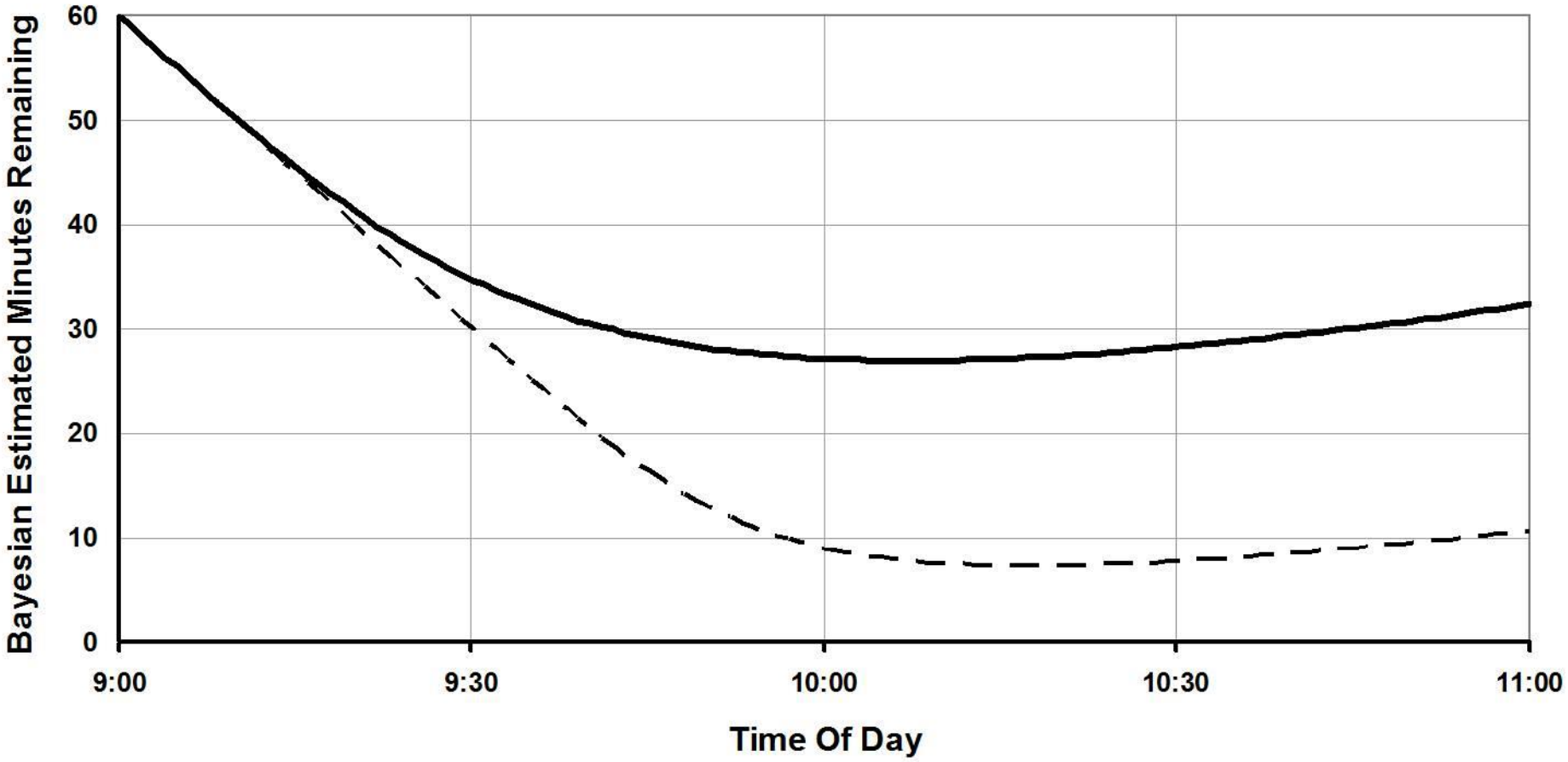


Dexter F et al. Anesth Analg 2009

Non-Preemptive Tasks of Uncertain Durations

- Why flat curve for durations > estimated?
  - Statistical property of two parameter log normal distributions with small variance terms
  - Many procedures continue until surgery done, and then closing and wakeup takes 30 min

Tiwari V et al. Anesth Analg 2013

Non-Preemptive Tasks of Uncertain Durations

- Among the 50% cases ongoing at 10:00, estimated time remaining is 30 min

Non-Preemptive Tasks of Uncertain Durations

- Among the 50% cases ongoing at 10:00, estimated time remaining is 30 min
  - Among the 23% cases ongoing at 10:30, estimated time remaining is 30 min

Non-Preemptive Tasks of Uncertain Durations

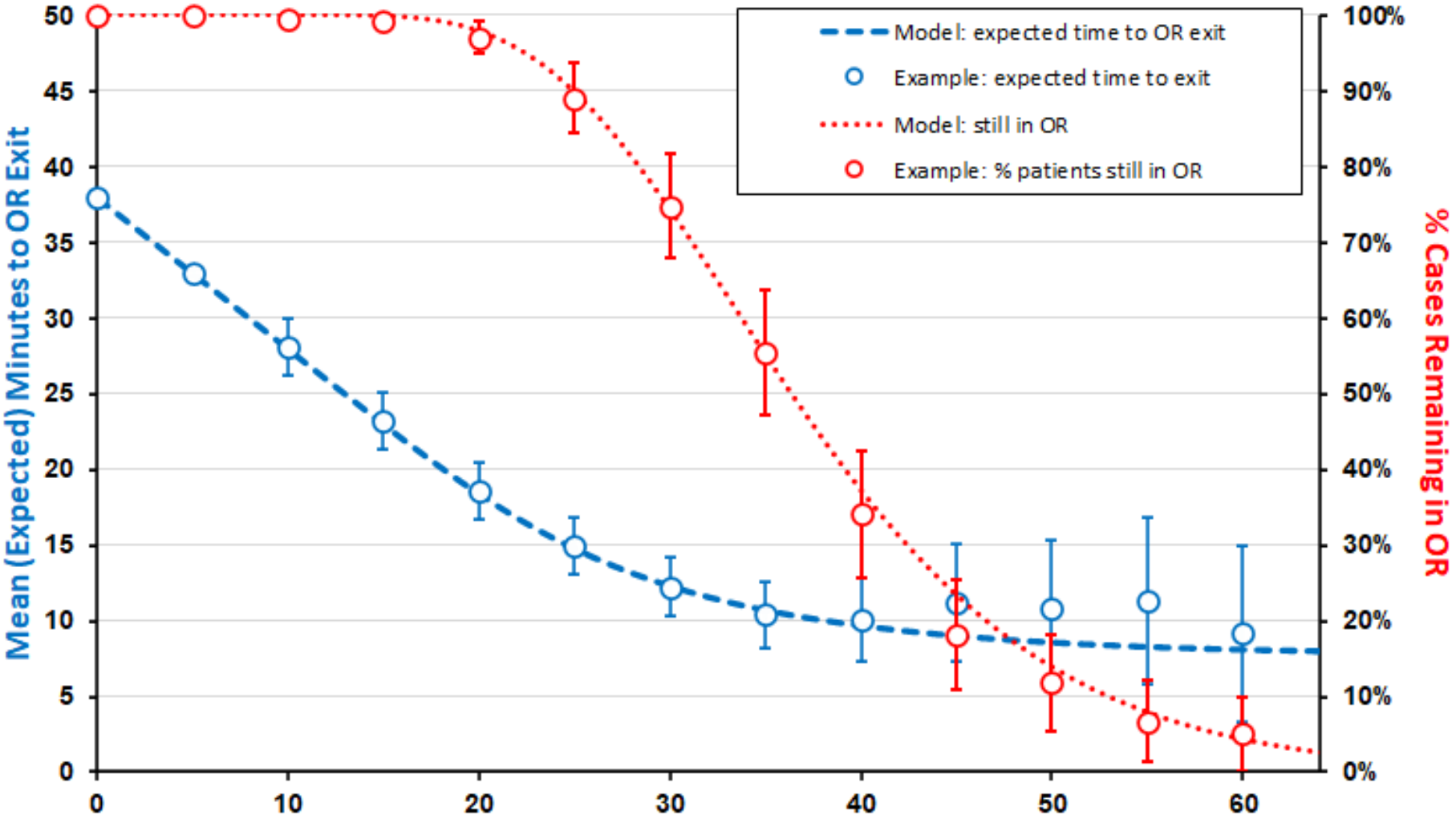
- Among the 50% cases ongoing at 10:00, estimated time remaining is 30 min
  - Among the 23% cases ongoing at 10:30, estimated time remaining is 30 min
    - Among the 11% cases ongoing at 11:00, estimated time remaining is 30 min

Non-Preemptive Tasks of Uncertain Durations

- Among the 50% cases ongoing at 10:00, estimated time remaining is 30 min
  - Among the 23% cases ongoing at 10:30, estimated time remaining is 30 min
    - Among the 11% cases ongoing at 11:00, estimated time remaining is 30 min

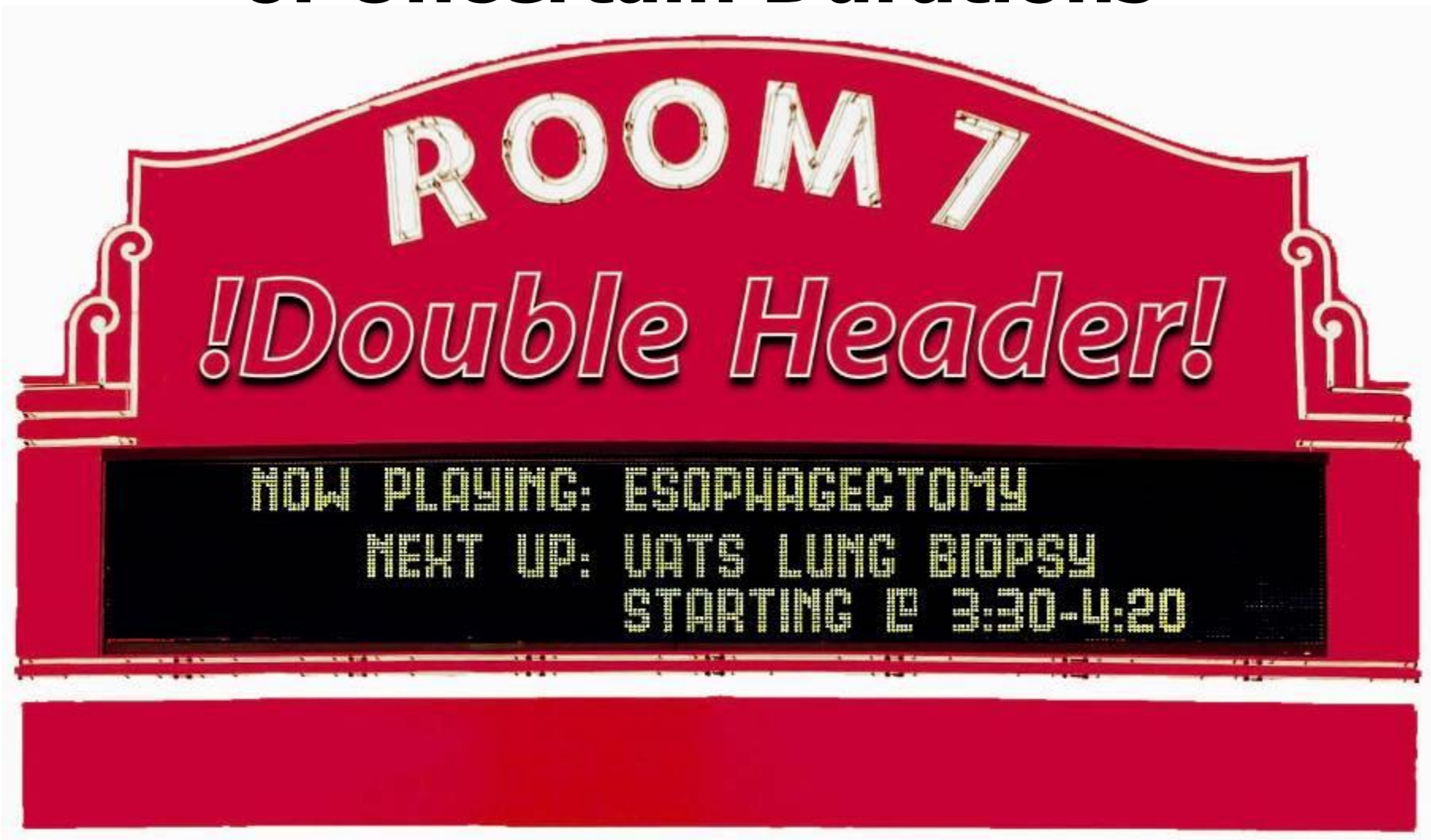
➢ If query OR for time remaining, record 30 min remaining, not 10:30 or 11:00

Minutes from Start of Surgical Wound Closure to OR Exit



Epstein RH et al. Periop Care Oper Room Manag 2022

Non-Preemptive Tasks of Uncertain Durations



Review – Summarize the Facts of the Talk

Apply Results Learned About Time Remaining in Cases

Apply Results Learned About Time Remaining in Cases

- Person with clipboard managing late running cases
  - If at 3:10 an OR expects "50 minutes more," what should be written on the clipboard?
- Designer (purchaser) of OR white boards
  - What statistical feature important? What ask?
- Surgeon who wants more of her operating rooms lists of cases to start on time
  - How should surgeon plan clinic and operating room schedules?

Additional Information on Operating Room Management

- www.FranklinDexter.net/education.htm
  - Example staffing reports with calculations
  - Lectures on OR allocation and staffing, anesthesia staffing, PACU staffing, financial analysis, drug and supply costs, 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