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

 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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- 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



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



- Ann parks in Ramp A, because it is closer to the Starbuck's – she wants to get a cappuccino while waiting
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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



- 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



 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

Prahl A et al. Anesth Analg 2013



- 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



#### 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

 Hospital, hospital and anesthesia providers, hospital and physicians, or society


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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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- Costs differ depending on basis for decision
  - Hospital, hospital and anesthesia providers, hospital and physicians, or society
- Costs differ depending on staff scheduling and assignment decisions
  - Even when nursing, anesthesia, and surgeons follow the same ordered-priorities, if based on labor costs they make different decisions
- Decisions based on OR efficiency invariant to these issues



- 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?



 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



- 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)

Dexter F, Traub RD. Anesth Analg 2002 Dexter F et al. Anesthesiology 2004



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#### Constant

#### Implication

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



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#### Constant

#### Implication

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



#### 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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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
     <u>Dexter F et al. Anesthesiology 2004</u>

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#### Scenario

- Staffing is planned from 8 AM to 3:30 **6** PM
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#### Scenario

- Staffing is planned from 8 AM to 3:30 **6** PM
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- Fast anesthesiologist increased did not increase OR efficiency

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 <u>access</u> 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. <u>Personal satisfaction</u>

- 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?



- 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



- Staffing is planned from 7:15 AM to 3:30 6 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
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- Which OR should anesthesiologist start next?



- 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 + 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



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



- 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



- 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



- 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
- Staffing is planned from 7 AM to 3:30 6 PM
- Which OR should housekeeper clean first?



- Patient safety is unaffected by the decision
- 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



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



- 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

- 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 2<sup>nd</sup> 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?



- 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



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

Dexter F et al. Anesthesiology 2004



- 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



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  - 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



- Hospital has one team to work past 3 PM – Team will not finish its case until 10 PM
  - At 2 DM all athen ODe have recently finishe
- 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?

- 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



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Dexter F et al. J Clin Anesth 2003



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# 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

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  - 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



- 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?



#### 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



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- Patient and surgeon waiting
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  - Start the case now
- > Why important?



### 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?



- 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



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

Dexter F et al. Anesth Analg 2016



- 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



#### 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 4<sup>th</sup> OR other than for safety reasons, because would first fully fill the 3 ORs, which has never happened



#### 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 4<sup>th</sup> OR other than for safety reasons, because would first fully fill the 3 ORs, which has never happened

Staffing ≠ maximum # ORs at same time

- 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?



- 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



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



- 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
- At 6:10 PM, notify orthopedic resident of delay



- 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



- 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 overutilized 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



- 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?



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



- 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



- 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



- 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



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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?



#### • 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



- 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



- 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?

- Staffing planned from 7 AM to 5 PM
- Time remaining in ORs at 2 PM
  - <u>3 hours</u> 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?

- 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



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- 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



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

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 <u>equally precisely</u> 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

- Without loss of generality, can think of OR case duration estimation about achieving on-time starts of subsequent cases
  - Only exception is the single very long duration case that would fill entire workday



## Achieving On-Time Starts Through Information

- Without loss of generality, can think of OR case duration estimation about achieving on-time starts of subsequent cases
  - Only exception is the single very long duration case that would fill entire workday
- Largest adverse effect is on the to-follow surgeon in the same OR on same day

Wachtel RE, Dexter F. Anesth Analg 2009



## Achieving On-Time Starts Through Information

- Throughout lecture, "> 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


- Throughout lecture, "> 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 2<sup>nd</sup> surgeon in an OR that day

 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

- 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

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

30%

Dishon-Berkovits M, Berkovits R. Fractals 1997

• What % worker days with tardy arrival? 0% 3% 10% 13% (9496 / 73,768 work days) 20% 23% 30%



Approximately half of the tardy arrivals are within how many minutes?
5 minutes
15 minutes (when pay reduced)
30 minutes
60 minutes
120 minutes

Dishon-Berkovits M, Berkovits R. Fractals 1997

- Approximately half of the tardy arrivals are within how many minutes?
  - 5 minutes
  - 15 minutes (when pay reduced)
  - 30 minutes
  - 60 minutes 120 minutes





- Notification to patient care assistants 45 min before OR start time to go to selected 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)</li>

Brown MJ et al. J Healthc Qual 2015



- 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., 5<sup>th</sup> percentile) or "longest possible" (e.g., 90<sup>th</sup> 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., 5<sup>th</sup> percentile) or "longest possible" (e.g., 90<sup>th</sup> 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



 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?

- 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



- Patient and surgeon waiting does not relate to mean historical case duration
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# 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:
    - 1<sup>st</sup> relies on the mean of all the times that she previously drove to the airport
    - 2<sup>nd</sup> 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



Dexter F, Ledolter J. Anesthesiology 2005

## Value of Estimated Duration From Surgeon



Dexter F, Ledolter J. Anesthesiology 2005



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







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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



- 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

*I successively calculated mean as I added more historical 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 3.59 hr 3) 4.38 hr 4) 4.00 hr 3.69 hr Final value for 5) 3.15 hr 3.58 hr comparison 6) 3.42 hr 3.56 hr 7) 4.38 hr 3.67 hr 8) 3.33 hr 3.<u>63</u> hr 3.65 hr

9) 3.77 hr

Case durations listed sequentially for one surgeon performing total hip replacement 3.62 hr 1) 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



Incremental reduction in error in predicting mean case duration small once  $\geq$  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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- 8) 3.33 hr
- 9) 3.77 hr

-0.03 hr -0.88 hr 0.73 hr 0.35 hr

- -0.40 hr
- -0.23 hr
- 0.73 hr
- -0.32 hr
  - 0.12 hr

*Difference from mean of 3.65 hr* 

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
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- 0.35 hr
  - -0.40 hr
  - -0.23 hr
  - 0.73 hr
  - -0.32 hr
    - 0.12 hr



- Case durations listed sequentially for one surgeon performing *total hip replacement*
- 1) 3.62 hr
- 2) 2.77 hr
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  - -0.23 hr
- 0.73 hr
- -0.32 hr
  - 0.12 hr

*Results markedly underestimate the problem at a hospital surgical suite* 

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



- 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



- 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



# 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



# **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**

- 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

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

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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  - Typically performed in operating room
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  - Many very rare, but with combinations, even with 1 quarter of data, observe 49,548

O'Neill L et al. J Clin Anesth 2017



- 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



- Characteristics of a hospital surgical suite
  - 11,579 cases
  - 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



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



 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

 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



# **Cannot "Borrow" Data from Other Hospitals or Insurers**

- Mean case durations for same procedure differ markedly among hospitals (P < 0.0001)</li>
   Heterogeneity statistic I<sup>2</sup> = 96%!
- Coefficients of variation of case durations (i.e., standard deviations in log scale) also differ markedly among hospitals (P < 0.0001)</li>

Dexter F et al. Anesth Analg 2013



### **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

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

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



- 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



- 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**

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# Scheduling Cases Using Bin Packing Methods

- Case duration estimation to choose operating rooms by taking means of historical data
- 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

Dexter F, Traub RD. Anesth Analg 2002



# Scheduling Cases Using Bin Packing Methods

- Case duration estimation to choose operating rooms by taking means of historical data
- 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 6.5 hr 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?
- 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 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



# **Implication of the Good Performance**

- Negligible ROI from improved 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
- Does this mean poor ROI from decisionsupport software to assist managers in scheduling cases?


# **Implication of the Good Performance**

- No! 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*



- Staffing planned 1 OR for 11 hr, 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

Pandit JJ, Tavare A. Eur J Anaesthesiol 2011 Wang Z, Dexter F. Periop Care Oper Room Manag 2022

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Pandit JJ, Tavare A. Eur J Anaesthesiol 2011 Wang Z, Dexter F. Periop Care Oper Room Manag 2022



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



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  - 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



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



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



Resequencing day before and day of surgery	Νο		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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Wang Z, Dexter F. Periop Care Oper Room Manag 2022

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

- 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 day of surgery or within a few days of surgery, but months ahead before choose staff scheduling
    - <u>Service-specific operating room staffing</u>
    - Economics of reducing turnover times
    - <u>Reducing variability in anesthesia work hours</u>
       <u>by good decision-making in the scheduling office</u>

#### **Moving Cases**

Result is same as for case scheduling

 Benefit of information systems is not from improved case duration prediction, but how the estimated case durations are used

Dexter F. Anesth Analg 2000 Dexter F et al. Anesthesiology 2004



- 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



- 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



- 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



#### 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



#### 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
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- 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 2<sup>nd</sup> case for today
   4 hr case with the surgical microscope
  - 4 m case with the surgical microscope
- Yet, other surgeons have also requested OR time for briefer cases



Dr. A has two cases today in OR 1

1<sup>st</sup>: 2 hr case with the microscope
2<sup>nd</sup>: 6 hr case without microscope

Dr. B would have two cases in OR 2

1<sup>st</sup>: 3 hr case without the microscope
2<sup>nd</sup>: 4 hr case with the microscope



- Dr. A has two cases today in OR 1 -1<sup>st</sup>: 2 hr case with the microscope - 2<sup>nd</sup>: 6 hr case without microscope Dr. B would have two cases in OR 2 -1<sup>st</sup>: 3 hr case without the microscope - 2<sup>nd</sup>: 4 hr case with the microscope  $\succ$  OK if Dr. A finishes 1<sup>st</sup> case before Dr. B > How judge whether uncertainty in estimate of case duration may affect decision?
- For which cases?



- 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



- 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?



- 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%</li>

Dexter F, Traub RD. Anesth Analg 2000 Dexter F, Ledolter J. Anesthesiology 2005



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

- 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



- 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





One surgeon's strabismus cases

Dexter F, Ledolter J. Anesthesiology 2005



One facility's cerebral aneurysm clipping cases

Dexter F et al. Anesth Analg 2013



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



- 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



- 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,  $\approx$  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





- 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



- 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





Epstein RH et al. Cureus 2021

- 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**

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### 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 (≅ 1/3<sup>rd</sup> less) to 2.0 hr (≅ 1/3<sup>rd</sup> 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 (≅ 1/3<sup>rd</sup> less) to 8.0 hr (≅ 1/3<sup>rd</sup> 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



 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



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

# *Earliness Ratio* =

Actual Start Time - (Start of Workday + 30 min) Scheduled Start Time - (Start of Workday + 30 min)





**Scheduled Start Time** 

N historical cases to calculate prediction bound	19	59	99	199
Percent of Cases with the N for Suite/Service/Day of Week Combination	$\textbf{98} \pm \textbf{0.1\%}$	$\textbf{98} \pm \textbf{0.1\%}$	$\textbf{94} \pm \textbf{0.1\%}$	$80 \pm \mathbf{0.2\%}$
Out-of-Bounds Rate for Combinations with >99 Cases	$\textbf{4.9} \pm \textbf{0.1\%}$	$\textbf{5.0} \pm \textbf{0.1\%}$	$\textbf{5.1} \pm \textbf{0.2\%}$	$\textbf{4.9} \pm \textbf{0.2\%}$
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	$\textbf{0.45}\pm\textbf{0.01}$	$\textbf{0.23} \pm \textbf{0.01}$	$\textbf{0.17} \pm \textbf{0.01}$	$\textbf{0.10} \pm \textbf{0.01}$

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Percent of Cases with the N for Suite/Service/Day of Week Combination	$\textbf{98} \pm \textbf{0.1\%}$	$\textbf{98} \pm \textbf{0.1\%}$	$\textbf{94} \pm \textbf{0.1\%}$	$80 \pm \mathbf{0.2\%}$
Out-of-Bounds Rate for Combinations with >99 Cases	$\textbf{4.9} \pm \textbf{0.1\%}$	$\textbf{5.0} \pm \textbf{0.1\%}$	$\textbf{5.1} \pm \textbf{0.2\%}$	$\textbf{4.9} \pm \textbf{0.2\%}$
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	$\textbf{0.45} \pm \textbf{0.01}$	$\textbf{0.23} \pm \textbf{0.01}$	$\textbf{0.17} \pm \textbf{0.01}$	$\textbf{0.10} \pm \textbf{0.01}$

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

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

Scheduled	Physician 1			Physician 2		
start	Ready	Arrival	NPO	Ready	Arrival	NPO
time	time	time	liquids	time	time	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

Service = 2 physicians Day of Week = the physician

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
  - 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

### Time Remaining in Cases – Hypothetical Example

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


Hours	Probability	Hr into Case	Expected (Mean) Time Remaining
1	10%	0	2.6 hr
2	45%	1	1.8 hr
3	25%	2	1.6 hr
4	15%	3	1.3 hr
5	5%	4	1.0 hr



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2.6 hr = -0 + (1×0.1 + 2×0.45 + 3×0.25 + 4×0.15 + 5×0.05) / 1.0
1.8 hr = -1 + ( 2×0.45 + 3×0.25 + 4×0.15 + 5×0.05) / 0.9



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1.8 hr = -1 + ( 2×0.45 + 3×0.25 + 4×0.15 + 5×0.05) / 0.9
1.3 hr = -3 + ( 4×0.15 + 5×0.05) / 0.2



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- 2.6 hr =  $-0 + (1 \times 0.1 + 2 \times 0.45 + 3 \times 0.25 + 4 \times 0.15 + 5 \times 0.05) / 1.0$
- 1.8 hr = -1 + (  $2 \times 0.45 + 3 \times 0.25 + 4 \times 0.15 + 5 \times 0.05) / 0.9$ • 1.3 hr = -3 + (  $4 \times 0.15 + 5 \times 0.05) / 0.2$

After 2.6 hr, there is not 0 hr expected time remaining!



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











# Other Examples **2 Procedures Estimated** $\cong$ **1 Hr**

# Other Examples **2 Procedures Estimated** $\cong$ **1 Hr**



Dexter F et al. Anesth Analg 2009

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



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



- 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 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



- 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



# **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