

Reducing Variability in Anesthesia Work Hours by Good Decision in the Scheduling Office

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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)

Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Making good staff scheduling decisions to facilitate assignments the day before surgery
- Decision-making 1-2 days before surgery to reduce over-utilized time
- Review of bin packing principles



Example of *Under-Utilized OR Time*

- Allocated time is from 7:15 AM to 3:30 PM
 - These are hours into which cases are scheduled
- 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

McIntosh C et al. Anesth Analg 2006



Example of *Over-Utilized OR Time*

- Allocated time is from 7 AM to 3 PM
- OR's last case of the day ends at 6 PM
- There are 3 hr of *over-utilized OR time*
 - Over-utilized OR time is from 3 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



Calculating Allocated OR Time

- On Mondays, hospital currently plans 3 ORs for orthopedics, each OR for 10 hr
 - $3 \text{ ORs} \times 10 \text{ hr} = 30 \text{ hr}$
- On Mondays, total hours of orthopedic cases including turnovers follows a normal distribution with a mean of 30 hr
- Relative cost of 1 hr over-utilized OR time = $2.0 \times$ that of 1 hr under-utilized OR time

McIntosh C et al. Anesth Analg 2006

Pandit JJ, Dexter F. Anesth Analg 2009

Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 5 hr, a typical value
- Since workload follows a normal distribution, need inverse of normal distribution function
 - Ratio of 2.0:1.0 over-utilized: under-utilized
 - Excel "= NORM.INV(2/3, 30, 5)"
- The 66th percentile of the normal distribution function with mean 30 hr and standard deviation 5 hr equals ***32 hr***



Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = 5 hr, a typical value
- Using the mean of 30 hr, what OR allocation maximizes efficiency of use of OR time?
 - 1) 3 ORs : 2 × 8 hr, 1 × 10 hr
 - 2) 3 ORs : 1 × 8 hr, 2 × 10 hr
 - 3) 3 ORs : 0 × 8 hr, 3 × 10 hr
 - 4) 4 ORs : 4 × 8 hr, 0 × 10 hr
 - 5) 4 ORs : 3 × 8 hr, 1 × 10 hr
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Calculating Allocated OR Time

- Consider standard deviation of orthopedics' workload on Mondays = **10** hr, a large value
- Since workload follows a normal distribution, need inverse of normal distribution function
 - Ratio of 2.0:1.0 over-utilized: under-utilized
 - Excel "= NORMINV(2/3, 30, **10**)"
- The 66th percentile of the normal distribution function with mean 30 hr and standard deviation **10** hr equals **34 hr**



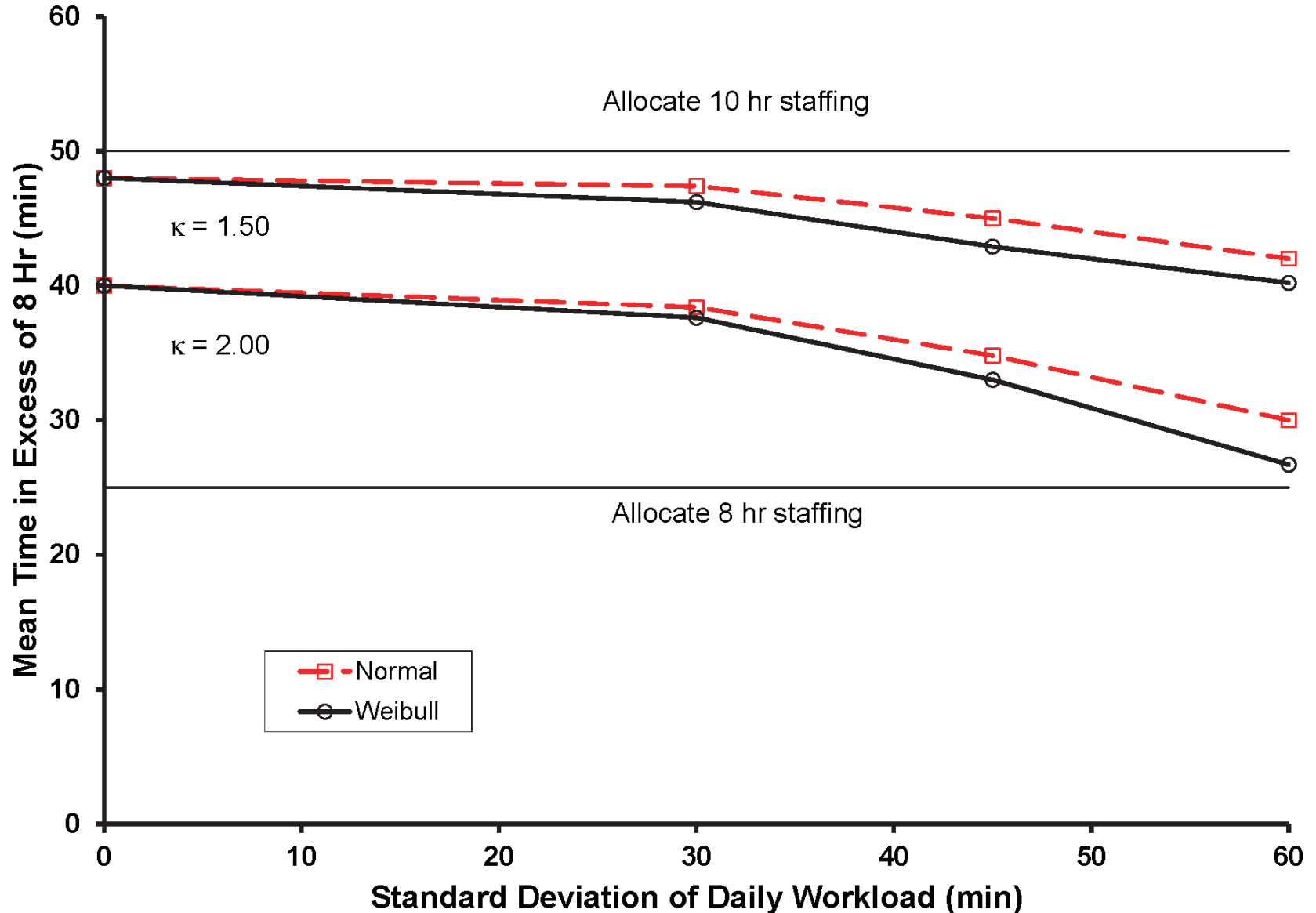
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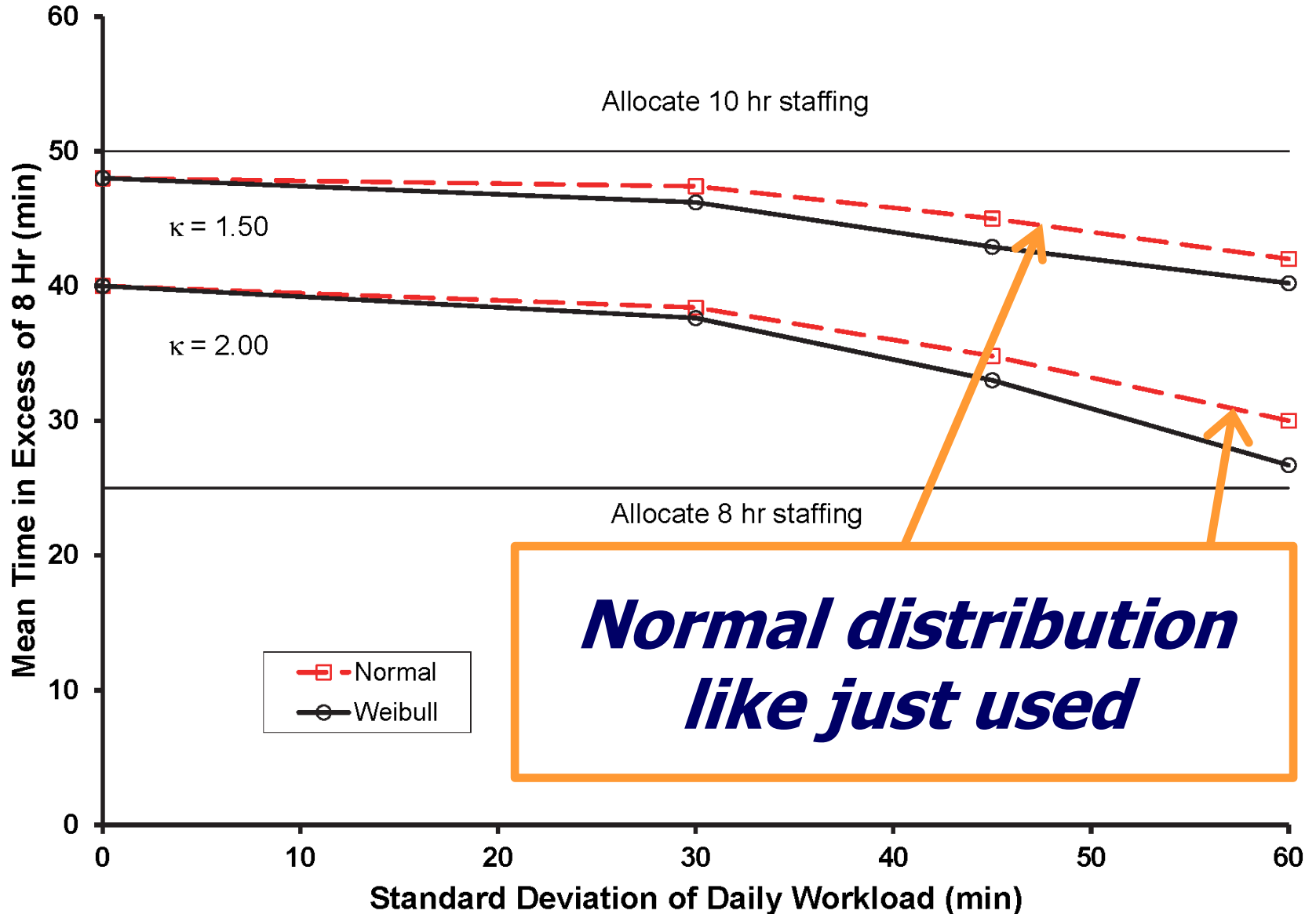
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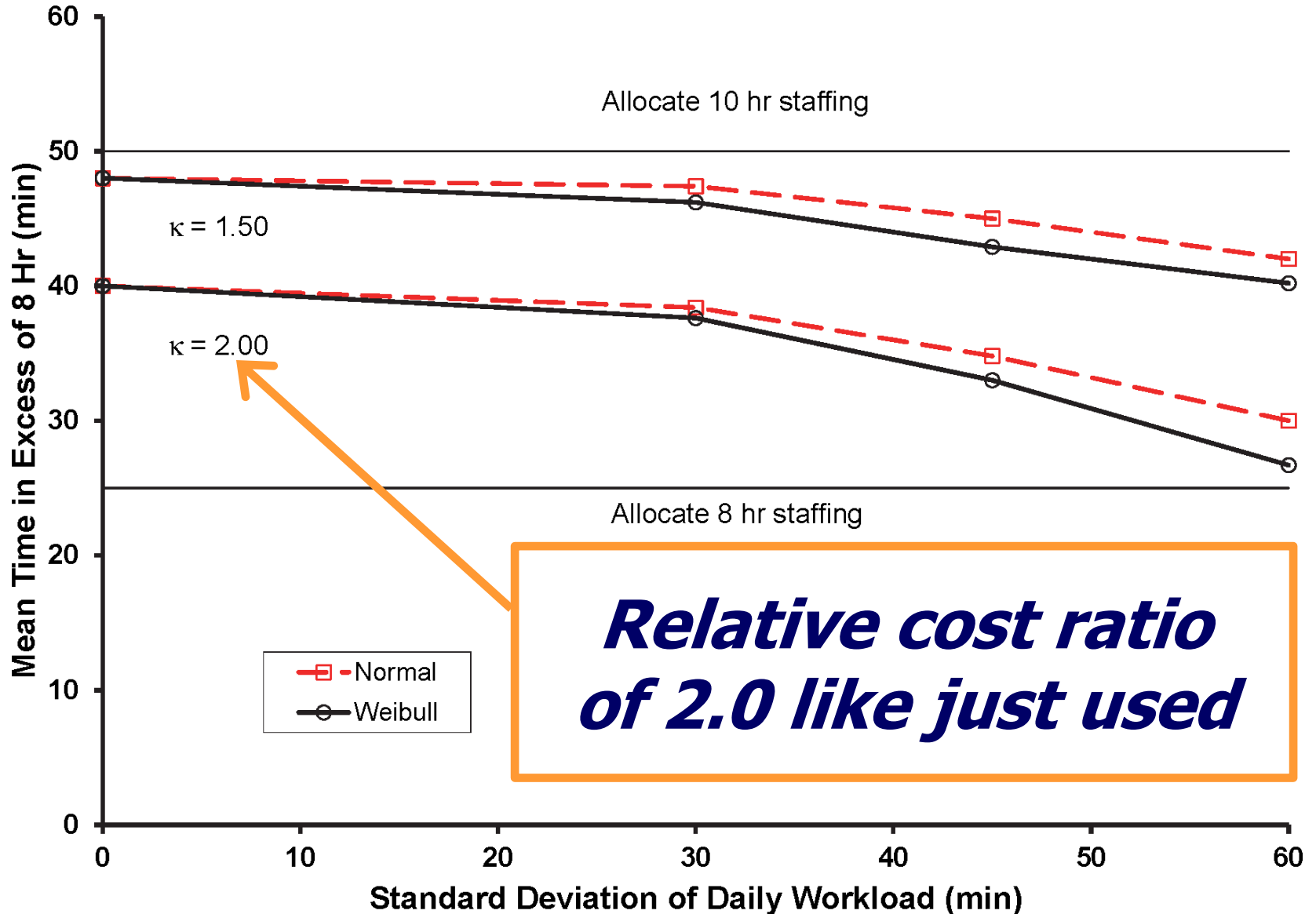
Allocated Times for Single ORs From Pandit & Dexter 2009



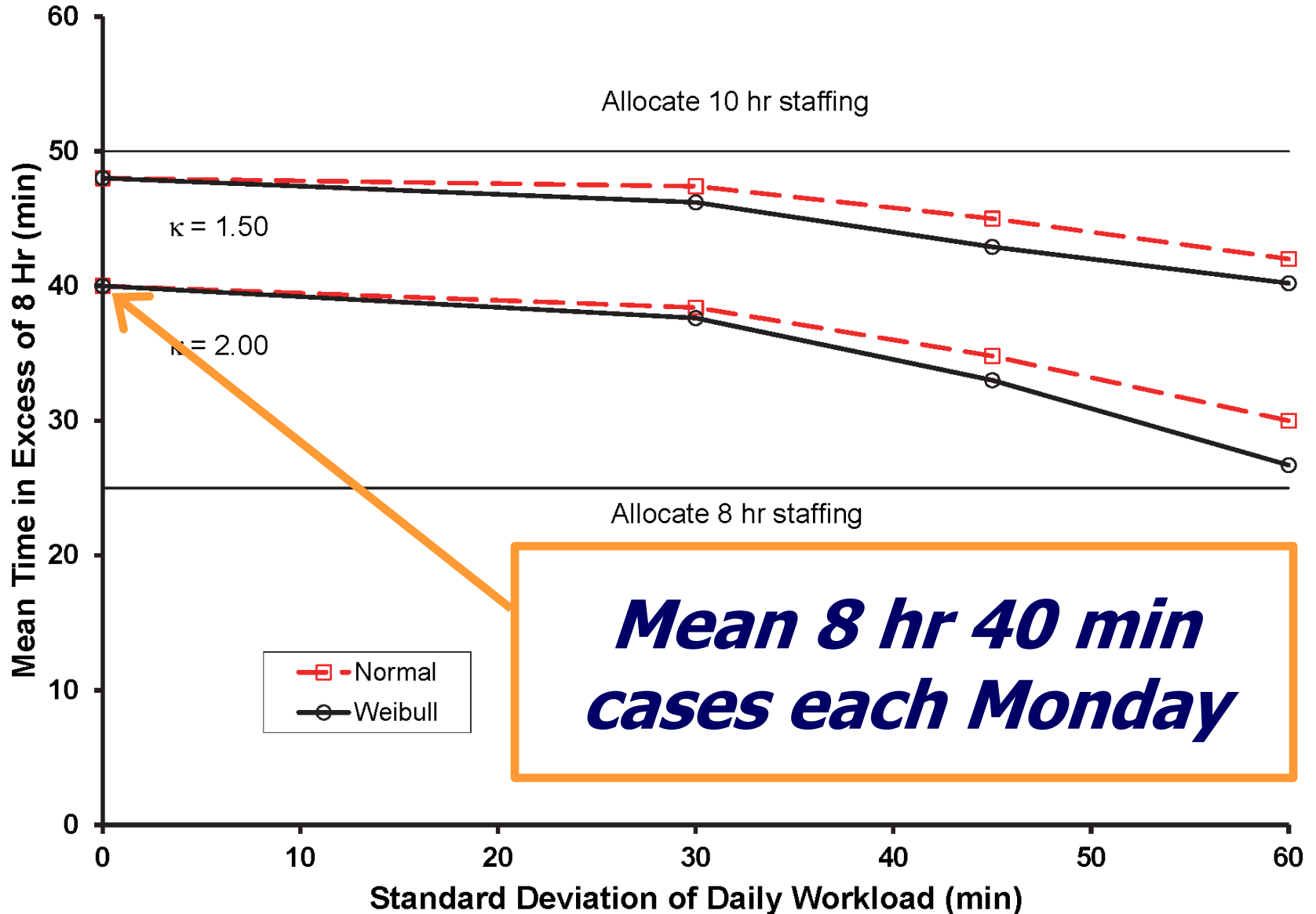
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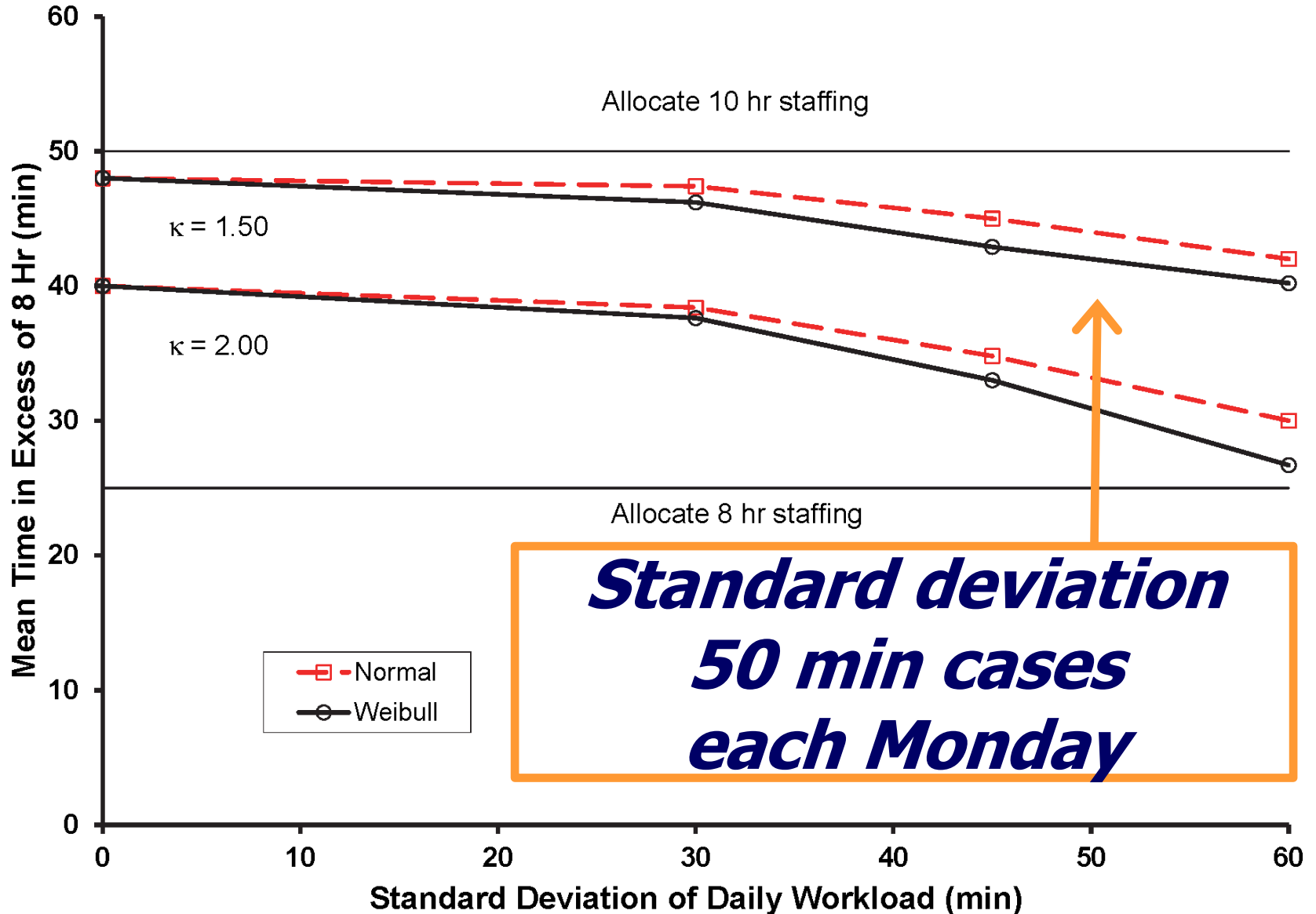
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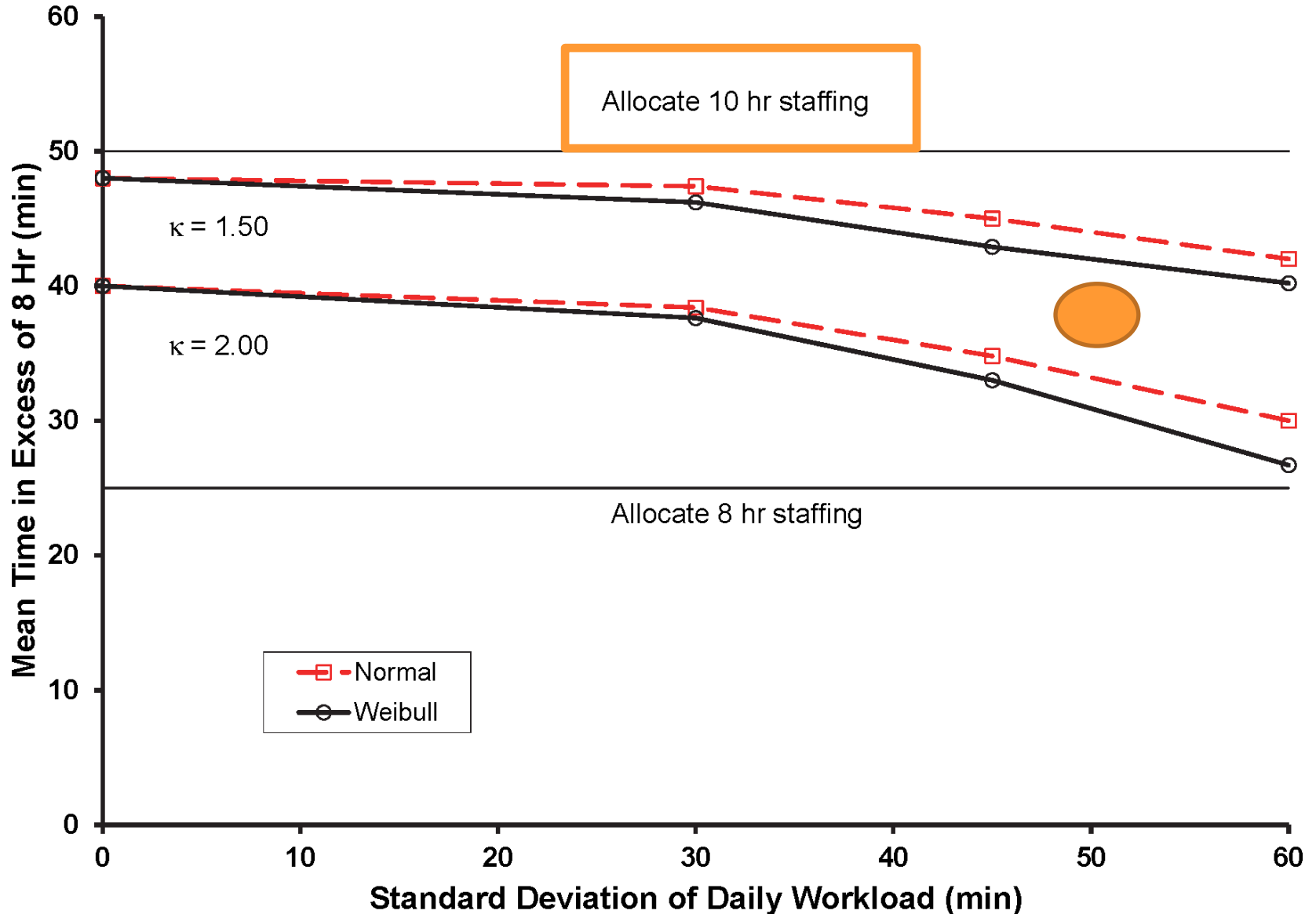
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Reducing Variability

- Vertical axis relates to mean
 - Commonly used to report adjusted utilization
- Horizontal axis relates to standard deviation



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- Since objective is to reduce ***variability*** in work hours, focus includes both mean and the standard deviation, principally the latter



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- Vertical axis relates to mean
 - Commonly used to report adjusted utilization
- Horizontal axis relates to standard deviation
- Since objective is to reduce ***variability*** in work hours, focus includes both mean and the standard deviation, principally the latter
- For monitoring reduction in variability and recognizing when and how it has been achieved, please see the previous talk online



Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Making good staff scheduling decisions to facilitate assignments the day before surgery
- Decision-making 1-2 days before surgery to reduce over-utilized time
- Review of bin packing principles



Increased Variability End of Day If Neglect Staff Scheduling

- Scenario for anesthesiologists using teams
 - Orthopedics' OR allocations are 4 ORs Mon, 3 ORs Tue-Thu, and 2 ORs on Fri

Lubarsky DA, Reves JG. J Am Coll Surg 2005



Increased Variability End of Day If Neglect Staff Scheduling

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 - Staff scheduling must then be by team and must include different numbers of allocated ORs for each day of the week

Dexter F et al. Anesth Analg 2010



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 - To start multiple peripheral nerve blocks in preoperative area on-time, staff scheduling also needs to include anesthesiologists' arrival times

Chelly JE et al. J Clin Anesth 2010



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 - Staff scheduling must then be by team and must include different numbers of allocated ORs for each day of the week
 - To start multiple peripheral nerve blocks in preoperative area on-time, staff scheduling also needs to include anesthesiologists' arrival times
- If plan for 3 ORs daily, anesthesia assignment office falsely appears to perform poorly each Monday

Application to Staff Scheduling and to Staff Assignment

- Service has multiple specialties, 10 hr staffing
- Resident physicians scheduling is one of the specialties, with policy that when no cases for the specialty they are not assigned other cases
 - On 1/3rd of workdays there are no cases of the specialty, and when ≥ 1 , mean 5.4 hr of cases

Application to Staff Scheduling and to Staff Assignment

- Service has multiple specialties, 10 hr staffing
- Resident physicians scheduling is one of the specialties, with policy that when no cases for the specialty they are not assigned other cases
 - On 1/3rd of workdays there are no cases of the specialty, and when ≥ 1 , mean 5.4 hr of cases
- Need to schedule nurse anesthetist for the 1/3rd of days' first case starts and for the afternoons: low observed productivity

Lunch Breaks

- Most prolonged turnovers occur middle of day

Dexter F et al. Anesthesiology 2005



Lunch Breaks

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- After first cases of day, period of day with the largest numbers of anesthesia providers needed is also middle of day because of lunch breaks (at hospitals with ORs lasting >8 hours)

Epstein RH, Dexter F. Anesthesiology 2012



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- Plan staff scheduling to have providers for all ORs during middle of day, no gap for breaks

Marjamaa RA et al. Health Care Manag Sci 2009

Smallman B et al. Anesth Analg 2013



Lunch Breaks

- Most prolonged turnovers occur middle of day
- After first cases of day, period of day with the largest numbers of anesthesia providers needed is also middle of day because of lunch breaks (at hospitals with ORs lasting >8 hours)
- Plan staff scheduling to have providers for all ORs during middle of day, no gap for breaks
- Use displays with evidence-based dynamic assignment of providers to ORs for breaks

Epstein RH, Dexter F. Anaesth Intensive Care 2012

Titler SS et al. Cureus 2021 and Breastfeed Med 2021

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Dexter F et al. Anesth Analg 2016



Working Fast Can Increase OR Efficiency

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- Allocated time is from 8 AM to 3:30 PM
- There are estimated to be 8.5 hr of cases
- Turnover and extubation times are brief
- OR finishes at 3:30 PM, instead of 4:30 PM
- Has OR efficiency been increased?



Working Fast Can Increase OR Efficiency

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- As approach the day of surgery, the cost of an hour of under-utilized OR time becomes 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 (\$) \cong
~~(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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Meaning of Maximizing OR Efficiency on Day of Surgery

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Constant

- Decisions made in the scheduling office to maximize OR efficiency are those that minimize the hours of over-utilized OR time



Working Fast Can Increase OR Efficiency

- Scenario
 - Allocated time was from 8 AM to 3:30 PM, which is 7.5 hr
 - Reducing turnover and extubation times resulted in cases finished 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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 - 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
 - Increased efficiency of use of OR time by preventing 1 hr of over-utilized OR time

Working Fast Can Increase OR Efficiency

- OR nurses, nurse anesthetists, and anesthesiologists are full-time employees
- Allocated time is from 8 AM to ~~3:30~~ **6** PM
- There are estimated to be 8.5 hr of cases
- Turnover and extubation times are brief
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McIntosh C et al. Anesth Analg 2006

Dexter F et al. Anesth Analg 2016



Working Fast Can Increase OR Efficiency

- Scenario

- Allocated time is from 8 AM to ~~3:30~~ **6** PM
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- No increase in OR efficiency

Good OR management operational decision-making is highly sensitive to the OR allocations, which is why those values used in scheduling office need to be calculated appropriately

Case Scheduling to Maximize OR Efficiency

- Allocated time for Ophthalmology Associates is 7:15 AM to 3:30 PM in OR 1 and OR 2
- Dr. Smith has scheduled cases in OR 1 that are scheduled to finish at 2 PM
- OR 2 is empty
- Dr. Reynolds wants an afternoon start
 - She asks to start an elective 3-hour case at 3 PM in OR 1
- Schedule the case into OR 1?



Scenario – Case Scheduling to Maximize OR Efficiency

- Starting the case at 3 PM would be expected to result in over-utilized OR time, thereby reducing OR efficiency
- Options available to Dr. Reynolds:
 - Take first case of the day start in OR 2
 - Choose a different workday

Dexter F et al. Anesth Analg 2012

Shi P et al. Anesth Analg 2016



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Case Scheduling to Maximize OR Efficiency

- Starting the case at 3 PM would be expected to result in over-utilized OR time, thereby reducing OR efficiency
- Options available to Dr. Reynolds:
 - Take first case of the day start in OR 2
 - Most facilities do not schedule an OR with over-utilized OR time when another allocated OR is empty
 - Choose a different workday



Case Scheduling to Maximize OR Efficiency

- Starting the case at 3 PM would be expected to result in over-utilized OR time, thereby reducing OR efficiency
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 - Take first case of the day start in OR 2
 - Choose a different workday
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 - Choose a different workday
 - She has OR time available every workday

Must get OR allocation right to PREVENT this scenario. Every case scheduling conflict is failure of OR allocation until proven otherwise.

Starting Late the Afternoon of Day Before Surgery, Target ORs

- At facilities where anesthesiologists supervise multiple ORs, they must effectively use staggered starts (\cong 20 min) of first cases of day, since otherwise they cannot be present at all critical portions of cases
 - Otherwise 1:2 MD:CRNA, lapses > 30% of days
 - Otherwise 1:3 MD:CRNA, lapses > 96% of days

Epstein RH, Dexter F. Anesth Analg 2012



Starting Late the Afternoon of Day Before Surgery, Target ORs

- Let the surgeons know so that those with the later starts are not waiting in the ORs

Koenig T et al. Anaesthesia 2011



Starting Late the Afternoon of Day Before Surgery, Target ORs

- Let the surgeons know so that those with the later starts are not waiting in the ORs
- Yes, preferentially focusing on ORs with over-utilized time, since ordered priorities are first performing all the cases safely and second reducing expected over-utilized time

Dexter F et al. Anesthesiology 2004

Dexter F et al. Anesth Analg 2007



Starting Late the Afternoon of Day Before Surgery, Target ORs

- Let the surgeons know so that those with the later starts are not waiting in the ORs
- Yes, preferentially focusing on ORs with over-utilized time, since ordered priorities are first performing all the cases safely and second reducing expected over-utilized time
- Important to understand since fixation on first case starts is due to cognitive bias that starting late results in all cases being tardy



Anesthesia Staff Assignment

- Some surgeons have significantly briefer turnover times when assigned to specific anesthesiologists
- For those surgeons, when possible, make assignment decisions to reduce turnover times
- Overall benefit is 6.8% reduction in median turnover times (95% CI 6.3% to 7.1%)

Doll D et al. Anesth Analg 2017



Anesthesia Staff Assignment

- End surgery to tracheal extubation (≥ 15 min) delays start next case, rated poorly by anesthesiologists, and important to surgeons

Apfelbaum JL et al. Anesth Analg 1993

Vitez TS, Macario A. J Clin Anesth 1998

Masursky D et al. Anesth Analg 2012

Dexter F, Epstein RH. Anesth Analg 2013



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Anesthesia Staff Assignment

- End surgery to tracheal extubation (≥ 15 min) delays start next case, rated poorly by anesthesiologists, and important to surgeons
- Odds ratio 2.10 ($P = 0.025$) for the 57% of cases when nurse anesthetist or resident physician worked with neurosurgeon < 5 previous cases

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Dexter F, Epstein RH. Anesth Analg 2013

Epstein RH et al. J Clin Anesth 2020



Anesthesia Staff Assignment

- Odds ratio 4.4 ($P = 0.005$) for the cases when the anesthesiologist worked with neurotologist < 5 previous cases
- Odds ratio 2.10 ($P = 0.025$) for the 57% of cases when nurse anesthetist or resident physician worked with neurosurgeon < 5 previous cases

Xia J et al. Otol Neurotol 2022

Epstein RH et al. J Clin Anesth 2020



Anesthesia Staff Assignment

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- Odds ratio 2.10 ($P = 0.025$) for the 57% of cases when nurse anesthetist or resident physician worked with neurosurgeon < 5 previous cases
- Threshold is <5 previous cases over 3 years, which at hospital was for 74% of cases, causing 23% prolonged extubations

Anesthesia Staff Assignment

- Anesthesia-controlled times, anesthesiologist & nurse anesthetist vs. & resident physician
 - (OR entrance until preparation can start) + (end of procedure [dressing on] until OR exit)
 - 2.5 min (SE 0.2) quicker, $P < 0.001$
- Turnover times, anesthesiologist & nurse anesthetist vs. & 1st year anesthesia resident
 - 2.6 min (SE 1.1) quicker, $P = 0.016$

Dexter F et al. Anesth Analg 1995

Urman RD et al. Ochsner J 2012

Hoffman CR et al. BMC Med Educ 2018



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Nurse Staff Assignment

- For each targeted OR
 - Assign senior nurse with expertise in the surgical specialty as lead
 - In addition to surgical technician and circulating nurse
 - Assign 2 dedicated PACU beds to the OR
- Significantly reduce non-operative time

Mascarella MA et al. Surgery 2016



Managerial Behavior

- When monitoring managers' performance, good criterion is use by their facility of either:
 - Displays providing recommendations
 - Displays providing information and checklists for how to use the information

Dexter F et al. Anesth Analg 2007

Stepaniak PS, Dexter F. Anesth Analg 2013



Managerial Behavior

- When monitoring managers' performance, good criterion is use by their facility of either:
 - Displays providing recommendations
 - Displays providing information and checklists for how to use the information
- Use anesthesia group – facility agreement to codify the performance criteria

Dexter F, Epstein RH. Anesth Analg 2008

Dexter F, Epstein RH. Anesth Analg 2015



Caution: Do Not ↓ Variability and Yet Net ↓ Productivity

- Productivity =
(clinical care provided / \$ per regular hour)
/ (allocated hours +
{ratio > 1} × over-utilized hours)



Caution: Do Not ↓ Variability and Yet Net ↓ Productivity

- Productivity =
$$\frac{(\text{clinical care provided} / \$ \text{ per regular hour})}{(\text{allocated hours} + \{ \text{ratio} > 1 \} \times \text{over-utilized hours})}$$
- Would have nearly zero over-utilized time if every surgeon had 2 ORs every day



Caution: Do Not ↓ Variability and Yet Net ↓ Productivity

- Productivity =
(clinical care provided / \$ per regular hour)
/ (allocated hours +
 $\{ \text{ratio} > 1 \} \times \text{over-utilized hours})$
- Would have nearly zero over-utilized time
if every surgeon had 2 ORs every day
 - But productivity would be extremely low



Caution: Do Not ↓ Variability and Yet Net ↓ Productivity

- Reduced productivity from 3 versus 2 anesthesia providers assigned to 2 ORs
- Increased productivity from 4 versus 3 anesthesia teams assigned to 3 ORs
- Increased productivity from 5 versus 4 anesthesia & nursing teams assigned to 4 ORs

Williams BA et al. Am J Anesthesiol 1998

Hanss R et al. Anesthesiology 2005

Torkki PM et al. Anesthesiology 2005



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- Reduced productivity from 3 versus 2 anesthesia providers assigned to 2 ORs
- Increased productivity from 4 versus 3 anesthesia teams assigned to 3 ORs
- Increased productivity from 5 versus 4 anesthesia & nursing teams assigned to 4 ORs
- Results insensitive to specific workflow

Marjamaa RA et al. Health Care Manag Sci 2009



Caution: Do Not ↓ Variability and Yet Net ↓ Productivity

- Reduced productivity from 3 versus 2 anesthesia providers assigned to 2 ORs
- Increased productivity from 4 versus 3 anesthesia teams assigned to 3 ORs
- Increased productivity from 5 versus 4 anesthesia & nursing teams assigned to 4 ORs
- Results insensitive to specific workflow
- Facilitate by coordinating dates surgeons operate (“blocks”) to best use the shared OR(s)



Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Making good staff scheduling decisions to facilitate assignments the day before surgery
- Decision-making 1-2 days before surgery to reduce over-utilized time
- Review of bin packing principles



Bin Packing Surgical 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

- Allocated time 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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- 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

- 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

- 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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Safety



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Reason for Add-on Surgical Case Scheduling Result

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



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- Reduces the hours of over-utilized OR time!



Topics of Talk on Reducing Variability

- Review of principles in calculating allocated OR time for use in reducing over-utilized time
- Making good staff scheduling decisions to facilitate assignments the day before surgery
- Decision-making 1-2 days before surgery to reduce over-utilized time
- Review of bin packing principles



Question and Answer #1

- OR time is allocated at a surgical suite either for 8 hours or 10 hours
- A service on Tuesdays has a mean of 8 hr 40 min with a standard deviation of 50 min
- Allocate 8 hr or 10 hr and why?



Question and Answer #1

- OR time is allocated at a surgical suite either for 8 hours or 10 hours
- A service on Tuesdays has a mean of 8 hr 40 min with a standard deviation of 50 min
- Allocate 8 hr or 10 hr and why?
- 10 hr maximizes efficiency of use of OR time



Question and Answer #2

- A studied surgical suite had some allocated ORs for 8 hours and other 10 hours, based on minimizing the inefficiency of use of OR time
- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- What are the two times of day that the largest numbers of anesthesia providers are needed?



Question and Answer #2

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- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- What are the two times of day that the largest numbers of anesthesia providers are needed?
 - First case starts and lunch breaks
 - Middle of the day, when there are also the largest numbers of turnovers

Question and Answer #3

- A studied surgical suite had some allocated ORs for 8 hours and other 10 hours, based on minimizing the inefficiency of use of OR time
- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- What is the consequence of 1 too few CRNAs at either of these 2 times of day when need the largest numbers of anesthesia providers?



Question and Answer #3

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- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- What is the consequence of 1 too few CRNAs at either of these 2 times of day when need the largest numbers of anesthesia providers?
 - Increased over-utilized OR time, since all cases should still be completed



Question and Answer #4

- A studied surgical suite had some allocated ORs for 8 hours and other 10 hours, based on minimizing the inefficiency of use of OR time
- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- When planning first case of day starts, how decide what ORs to stagger to start first? Last?

Question and Answer #4

- A studied surgical suite had some allocated ORs for 8 hours and other 10 hours, based on minimizing the inefficiency of use of OR time
- Anesthesiologists supervise CRNAs, some ORs 1:2 and some 1:3
- When planning first case of day starts, how decide what ORs to stagger to start first? Last?
 - Start first OR(s) with over-utilized time
 - Start last OR(s) with most under-utilized time

Additional Information on Operating Room Management

- www.FranklinDexter.net/education.htm
 - Full course (e.g., medical directors and analysts)
 - Lectures on day of surgery decision making, case duration prediction, allocating OR time, increasing anesthesia productivity, financial analysis, and strategic decision-making
- www.FranklinDexter.net
 - Comprehensive bibliography of peer reviewed articles in operating room and anesthesia group management
 - Sign-up for notifications of new articles