

# Using Optimization Techniques to Improve Residency Scheduling in Pediatric Emergency Medicine

Mayo Clinic SE/OR Seminar Series

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# Outline

- ▶ Brief introduction to the UM Center for Healthcare Engineering and Patient Safety (*CHEPS*)
- ▶ Research on scheduling residents for pediatric emergency medicine rotations
- ▶ Discussion

University of Michigan  
Center for Healthcare  
Engineering and Patient  
Safety (*CHEPS*)

# *CHEPS*

- ▶ History and motivation
- ▶ Leadership and membership
- ▶ Current activities, research partnerships, etc.
- ▶ Educational activities
- ▶ ERC proposal preparation

# Scheduling Pediatric Emergency Medicine Residents at UMHS

# Acknowledgements

- ▶ Ongoing collaboration with many talented contributors
  - Spring 2011 Team
    - UMHS Chief Resident: Dr. Dan O'Connell
    - Students: Xun Xu, Kathy Lu, Marcial Lapp
  - Summer 2011 Team
    - UMHS Chief Resident: Dr. Brian Jordan
    - Students: Siyuan Sun, Jinshuai Guo, Marcial Lapp
  - Fall 2011 Team
    - UMHS Chief Resident: Dr. Brian Jordan
    - Students: Yiwen Jiang, Jinshuai Guo
  - Winter 2012 Team
    - UMHS Chief Resident: Dr. Brian Jordan
    - Students: Jinshuai Guo, Young-Chae Hong
  - Spring/Summer 2012 Team
    - UMHS Chief Resident: Dr. Micah Long
    - Students: Young-Chae Hong, Boying Liu, Tara Lynn O'Gara, Mindy Alberty

# What is medical residency?

- ▶ Transition period between medical school and fully independent/unsupervised practice
  - Four years of med school
  - First year of residency – “Intern”
  - Two more years of residency
  - Possibly one or two additional years as “Chief Resident”
  - Possibly more years as a “Fellow”
- ▶ During all of this time, providing patient care (albeit with the oversight of a more senior “attending” physician –supervision decreases over time)

# What is medical residency?

- ▶ A key issue: Dual role of residency
  - Learning experience: Residency (and Fellowship) are parts of the medical education training process
  - Patient care: Residents/Fellows provide a significant amount of the patient care in teaching hospitals and the associated clinical system
- ▶ A typical resident might engage in all of the following activities:
  - “Continuity clinics”
  - Shifts on service
  - Seminars, formal educational activities
  - Research

# Inherent Time Conflicts

- ▶ How to schedule residents' time
  - Need adequate patient coverage with a limited pool of residents
  - Need adequate training opportunities
  - Need adequate rest – fatigue increases risk of error
  - Need to address resident satisfaction, personal life
- ▶ Not just quantity of hours but pattern
  - Continuity of care
  - Sleep issues (especially associated with overnight shifts)
  - Opportunities for different medical experiences

# What is the general problem?

- ▶ Given a set of residents to be trained and a set of shifts to be covered, build a schedule that satisfies all patient care, educational, and other requirements
  - Build the schedule in a timely fashion
  - Be equitable
  - Satisfy personal requests where possible
  - Be flexible when changes arise

# What is our specific problem?

- ▶ Assigning residents to shifts to coverage the pediatric emergency department in Mott Children's Hospital at UMHS
- ▶ Eight overlapping shifts per day
- ▶ Month-long schedule (but conflicting *switch dates* depending on the resident)
- ▶ Approximately 15 residents per month, coming from four or five different residency programs

# What are the rules?

- ▶ Patient care requirements:
  - 8 overlapping shifts every day of the month
  - Every shift has to have exactly one resident assigned
  - Exceptions: 10a – 7p and 12p – 9p shift coverage is optional
    - Not *all* of these shifts can be left uncovered for the entire month
    - Ideally one of the two “flex shifts” should be covered each day
  - Certain shifts cannot be assigned to an intern
  - Certain overlapping pairs of shifts require a Peds resident on at least one of the two shifts
  - ...

# What are the rules?

## ▶ Resident availability

- Senior residents switch on the first of the month
- Interns switch on the 27<sup>th</sup> of the preceding month
- Pre-assigned vacation time must be respected
- Continuity clinics/post CC
- Some shifts are pre-assigned to certain residents/programs
- 10-hour rule
- First and last shifts must recognize boundaries of other rotations
- ...

# What is the current state?

- ▶ Schedules typically built by Chief Residents
- ▶ Limited decision support
- ▶ No formal training
- ▶ Hard to satisfy all rules
- ▶ Unlikely to make everyone happy

# Why is it hard to schedule manually?

	6		1	4		5	
		8	3		5	6	
2							1
8			4	7			6
		6				3	
7			9	1			4
5							2
		7	2	6	9		
	4		5	8		7	

- ▶ The more squares you fill in, the fewer choices you have left for what is valid
- ▶ Once you make a mistake, you might not know it for a long time
- ▶ Once you realize something is wrong, it can be very hard to back track and correct
- ▶ If a requirement changes, you have to start from scratch

# Why is it getting even harder?

- ▶ Number of residents is set and fixed externally (i.e. a program can't independently increase the number of residents to increase staffing)
- ▶ ACGME (American College of Graduate Medical Education) limits the amount of duty hours, patterns and frequency of time off, etc.
  - Have made some major increase to limitations in the past
  - Current talk about further tightening of restrictions
- ▶ This means there is not a lot of slack in the system, and it's likely to get worse

# Why should we care about this problem?

- ▶ Obvious concern: Time required of Chief Resident
- ▶ Secondary concern: Solution quality (rule violations)
- ▶ Third concern: Resident satisfaction
- ▶ But it's more than that...

# Why should we care?

- ▶ Schedule significantly impacts:
  - Continuity of care
  - Sleep patterns
  - Range of educational opportunities
- ▶ Lots of inherent conflicts here:
  - Reduction in consecutive work hours on duty can have short-term impact on patient safety and quality of care:
    - Reduce fatigue and thus improve patient safety
    - Increase hand-offs and thus decrease patient safety
  - Reduction in overall work hours can have long-term impact on patient safety and quality of care:
    - Improve resident quality-of-life, improve pipeline
    - Reduce number of learning opportunities, decrease quality of training

# Why should we care?

- ▶ It is virtually impossible for anyone to manually build a residency schedule that is error-free
- ▶ It is even less possible to incorporate issues of equity and personal preferences
- ▶ Sleep patterns and continuity of care issues get left aside entirely, except for ad hoc tweaks
- ▶ Errors in input data can mean re-starting from scratch with even less time to work on schedule quality

# Why should *we* care?

- ▶ This is exactly what we do!
  - Combinatorial optimization
  - Lots of interactions
  - Need a systematic approach to consider all parts concurrently

# How do we solve it?

- ▶ Mixed integer programming approach
  - $x_{r,s,d} = 1$  if resident  $r$  is assigned to shift  $s$  on day  $d$ , else 0
- ▶ Feasibility constraints are straightforward to model
- ▶ Run time using C++ and CPLEX on a standard PC is minimal (a few seconds at most)
- ▶ Finding a schedule that satisfies the rules is already progress over what exists (especially given time required)
- ▶ But not all feasible schedules are equally good

# How to “optimize”?

- ▶ Many different feasible schedules, not all equally good
- ▶ No one clear objective function, but many important metrics
  - Equity across residents
    - Number of shifts
    - Number of night shifts
    - General quality of schedule
  - “Bad sleep patterns”
  - Personal requests
  - Post-continuity clinic calls
  - Flex shift coverage
  - Transition shift coverage

# How to “optimize”?

- ▶ We could treat this as a multi-criteria objective function, assign weights to normalize, and solve
  - Weights are hard to find
  - Convergence can slow dramatically
- ▶ Is “optimal” the right goal???
  - Is this an engineering construct that we’re imposing inappropriately?

# How to “optimize”?

- ▶ Our approach:
  - Set boundaries on the metrics
  - Define as hard constraints
  - Search for a feasible solution
    - If found, review and decide what to tighten next
    - If not found, loosen the boundaries
  - Repeat until satisfied

# How is it working?

- ▶ Remarkably well!
- ▶ Schedule is of higher quality than manual schedules (dramatically)
- ▶ Chief Resident time requirement is much decreased
- ▶ “Buffer” to allocations of favoritism
- ▶ Ability to smoothly and quickly recover from data errors and last-minute changes
- ▶ “Unbelievable – this was literally a life saver. Amazing job – I’m very thankful.”

## Resident Scheduling Summary

Resident Name	Longest Work Period	Number of Shifts	Number of Night Shifts	Number of Post CC or Conf	Number of Bad Sleep Templates
EMsr1	2	10 (10,10)	0 (0,9)	0 (0,1)	0 (0,0)
Carter	5	9 (9,10)	3 (3,5)	0 (0,1)	0 (0,0)
Cooperstein	2	4 (4,5)	2 (2,3)	0 (0,1)	0 (0,0)
Ellsworth	4	17 (17,18)	6 (6,8)	0 (0,1)	0 (0,0)
Gorga	6	9 (9,10)	3 (3,5)	0 (0,1)	0 (0,0)
Lung	3	9 (9,10)	3 (3,5)	0 (0,1)	0 (0,0)
Pietrandrea	4	9 (9,10)	3 (3,5)	0 (0,1)	0 (0,0)
Shakkottai	3	4 (4,5)	3 (2,3)	0 (0,1)	0 (0,0)
Goldman	5	9 (9,10)	5 (3,5)	1 (0,1)	0 (0,0)
Quade	7	9 (9,10)	5 (3,5)	1 (0,1)	0 (0,0)
Yancon	4	9 (9,10)	5 (3,5)	0 (0,1)	0 (0,0)
Akers	5	17 (17,18)	7 (6,8)	0 (0,1)	0 (0,0)
Dazy	3	9 (9,10)	5 (3,5)	0 (0,1)	0 (0,0)
Kelker	4	10 (9,10)	5 (3,5)	1 (0,1)	0 (0,0)
Pesch	3	17 (17,18)	7 (6,8)	0 (0,1)	0 (0,0)
Snider	5	18 (17,18)	7 (6,8)	1 (0,1)	0 (0,0)
Gilbert	5	18 (17,18)	8 (6,8)	0 (0,1)	0 (0,0)
Hynymen	2	9 (9,10)	5 (3,5)	0 (0,1)	0 (0,0)
Mitchell	8	18 (17,18)	6 (6,8)	0 (0,1)	0 (0,0)
LPH1	1	1 (1,1)	0 (0,35)	0 (0,35)	0 (0,35)
LPH2	1	1 (1,1)	0 (0,35)	0 (0,35)	0 (0,35)
TPH1	1	1 (0,1)	0 (0,9)	0 (0,1)	0 (0,0)

10a-7p Flex Shift Coverage: 18 (15,40)

12p-9p Flex Shift Coverage: 22 (15,40)

Optional Shift Coverage: 5/15 (5,20)

# How is it working?

	#####	#####	#####	#####	#####	1-Jun-12	2-Jun-12	3-Jun-12	4-Jun-12	5-Jun-12	6-Jun-12
7a-4p	LPH1	LPH5	LPH9	LPH13	LPH16	Kofoed	Ward	Shin	EMsr1	Herbst	Bradford
9a-6p	Ney	Ney	Ney	Ney	TPH	Shin	Herbst	Auwarter	Snider	Kofoed	Snider
12p-9p	LPH2	LPH6	LPH10	-	LPH17	Duquette	-	-	Ward	Duquette	-
4p-1a	Snider	Covi	Snider	Covi	Snider	Covi	Covi	Duquette	Peacock	EMsr1	Covi
5p-2a	LPH3	LPH7	LPH11	LPH14	LPH18	Bradford	Bradford	Horton	Auwarter	Shin	Auwarter
8p-5a	Covi	Snider	Covi	Snider	Covi	Ney	Peacock	Ney	Bradford	Auwarter	Shin
11p-8a	LPH4	LPH8	LPH12	LPH15	LPH19	McNamara	McNamara	Bradford	Horton	Ward	McNamara

# How is it working?

	15-Jul-12	16-Jul-12	17-Jul-12	18-Jul-12	19-Jul-12	20-Jul-12	21-Jul-12
7a-4p	X	X	X	X	X	X	X
9a-6p			X				
10a-7p			X				
12p-9p			X				
4p-1a	Ellsworth		X				
5p-2a	X	X	X	X	X	X	X
8p-5a		X	Ellsworth	Ellsworth	Ellsworth	Ellsworth	
11p-8a	X	X	X	X	X	X	X
	22-Jul-12	23-Jul-12	24-Jul-12	25-Jul-12	26-Jul-12	27-Jul-12	28-Jul-12
7a-4p	X	X	X	X	X	X	X
9a-6p	Ellsworth		X			X	X
10a-7p			X			X	X
12p-9p			X		X	X	X
4p-1a		Ellsworth	X		X	X	X
5p-2a	X	X	X	X	X	X	X
8p-5a		X	Ellsworth	Ellsworth	X	X	X
11p-8a	X	X	X	X	X	X	X

# Where do we go next?

## ▶ Research

- When infeasible, why?
- More complex sleep patterns, cross-resident requirements/request, cross-day requirements/requests
- Generalization

## ▶ Practice

- Make operational/sustainable/affordable for Peds Emergency Medicine at UM
- Expand to other programs' Peds Emergency Medicine service
- Expand to other Peds services (e.g. NICU scheduling)
- Expand to other fields of residency (eg psych, surgery...)

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# What have we learned?

- ▶ You don't need to cure cancer to have impact
- ▶ You *do* need to invest time (a LOT of time!) to tackle real problems in healthcare
- ▶ It's not always optimal to look for optimal
- ▶ Doctors don't talk or think like engineers
- ▶ Engineers don't talk or think like doctors
- ▶ Relationships are invaluable and can be the basis of a long, productive line of collaborative research

