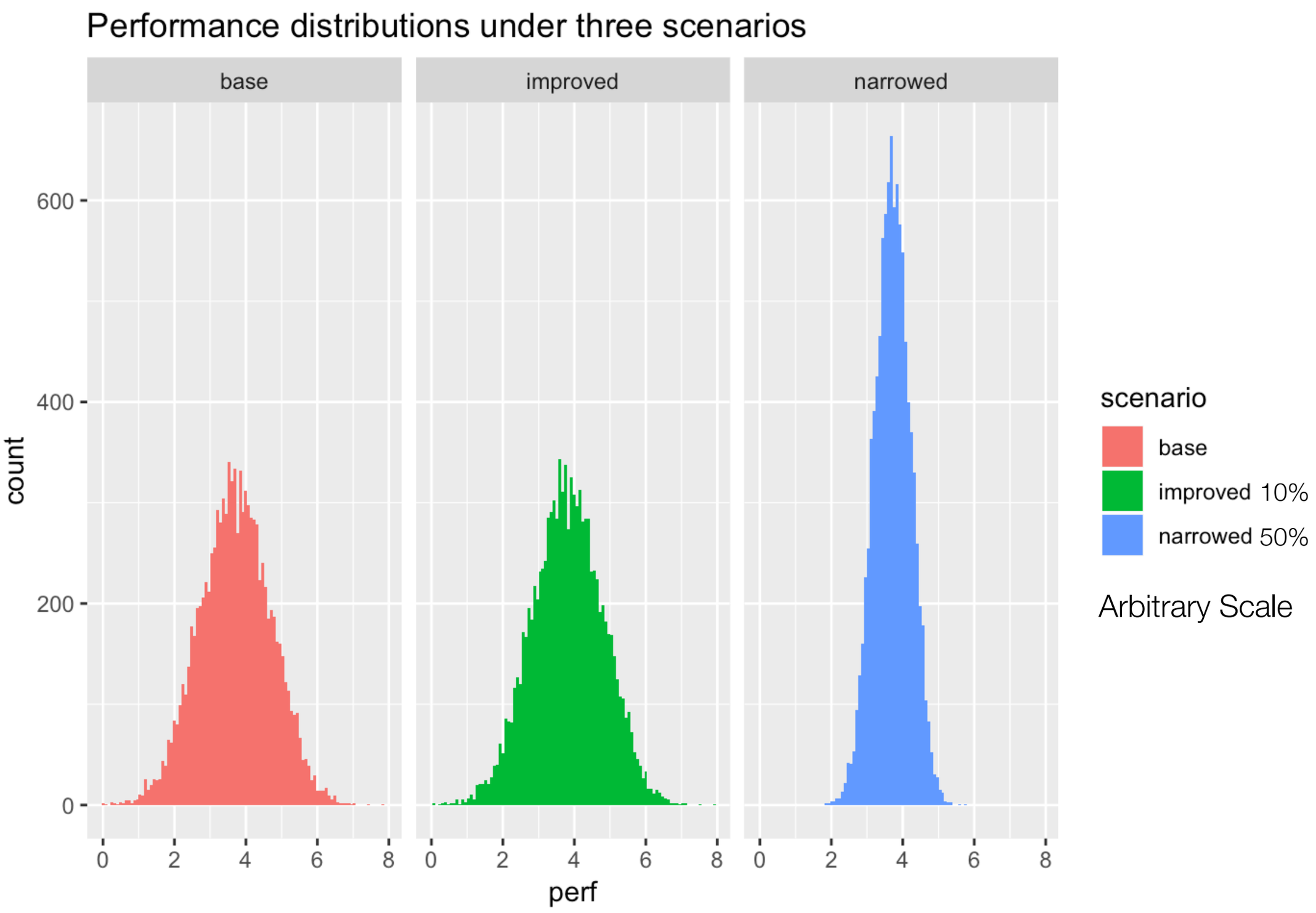
Automating Clinical Workflows

Massachusetts Institute of Technology

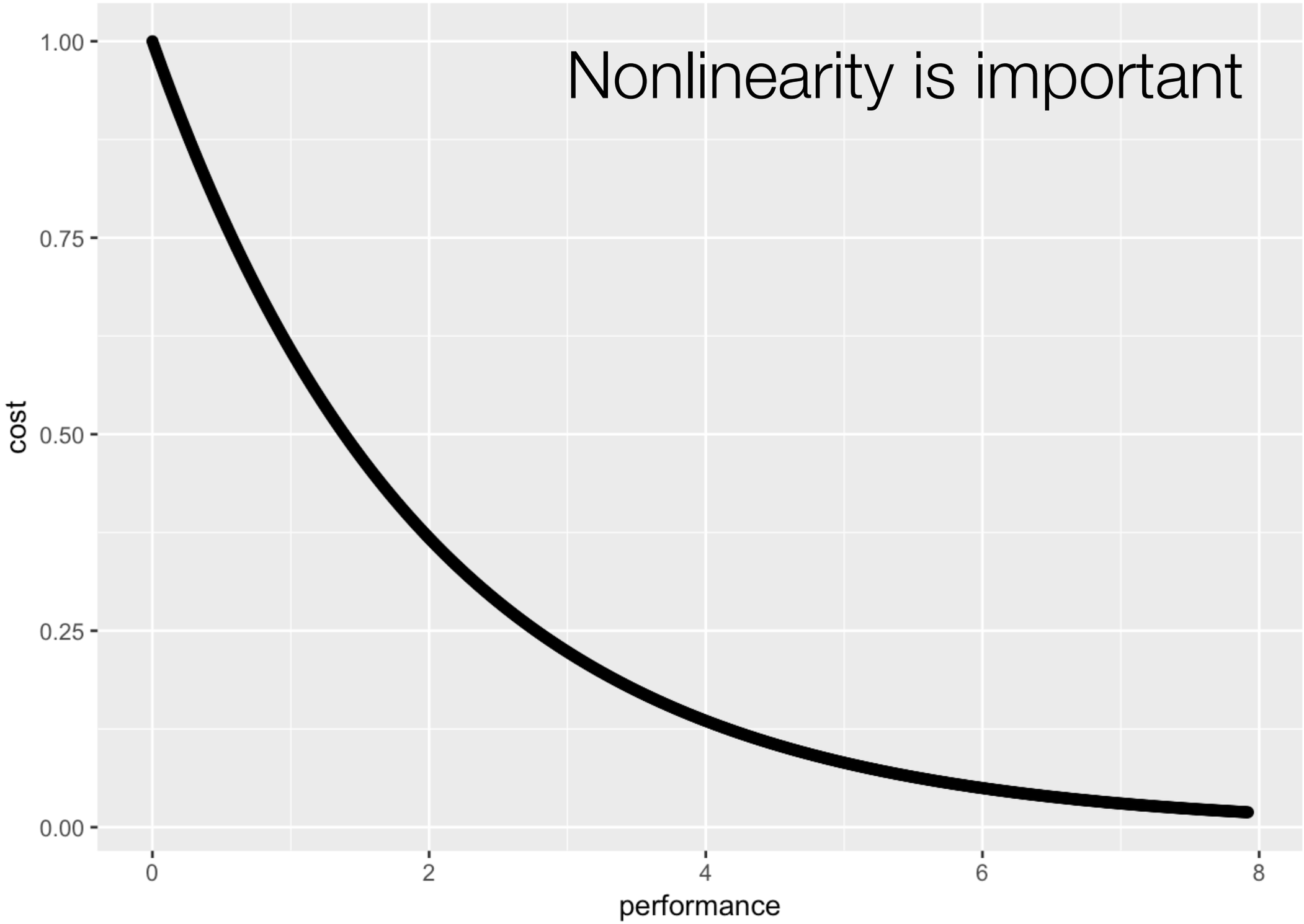
How to Improve Medical Care, Overall

- "Expert Systems" idea: understand what world-class experts do, and provide decision support to raise others' performance to that level
  - *improves average*
- "Protocol" idea: get everyone to treat similar patients in similar ways
  - *reduces variance*
- Which is better?
  - Depends on "loss function"
  - If worst performance is disproportionately more costly than best performance is less costly, then it's more important to eliminate the worst

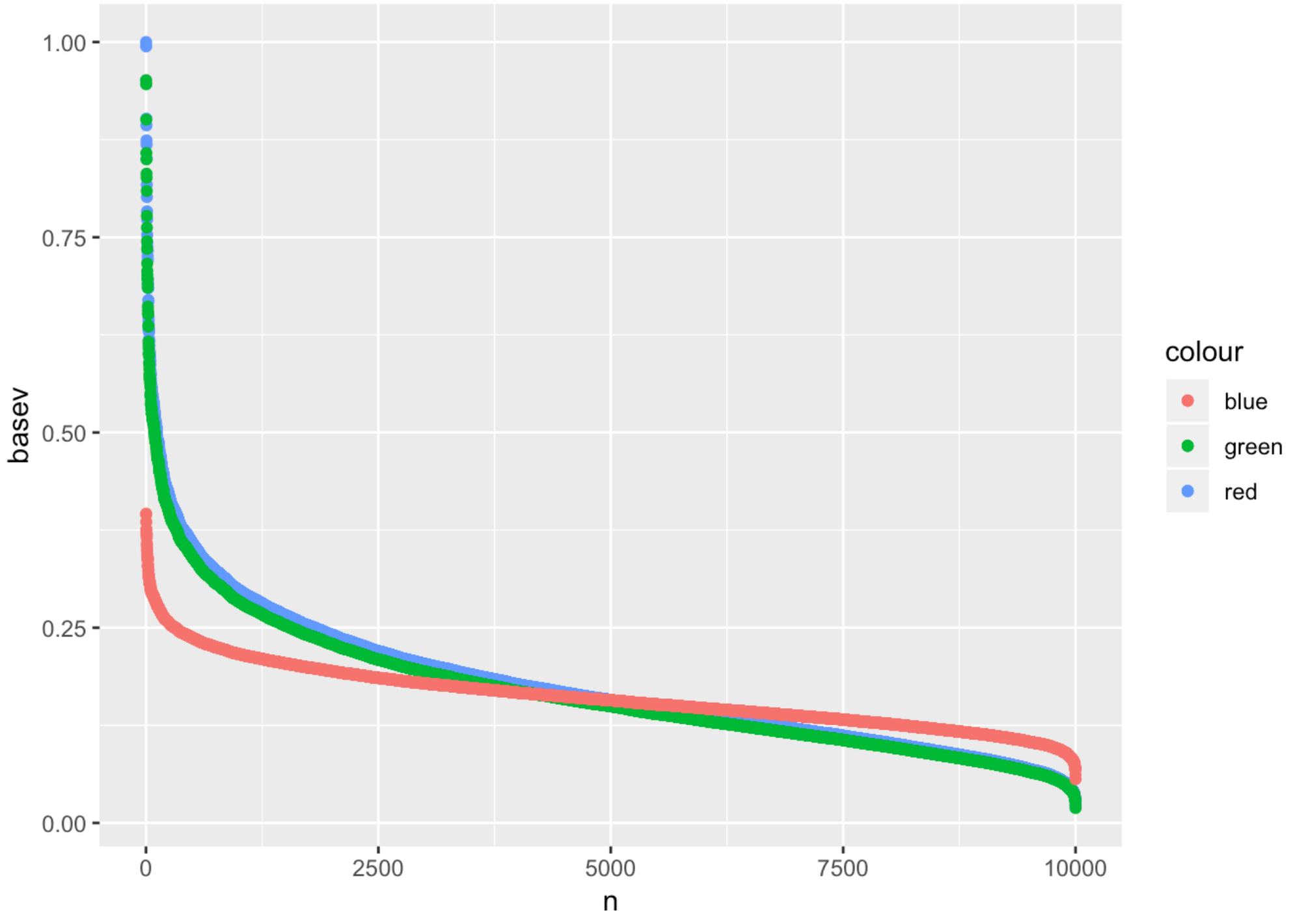
Hypothetical Clinician Performance



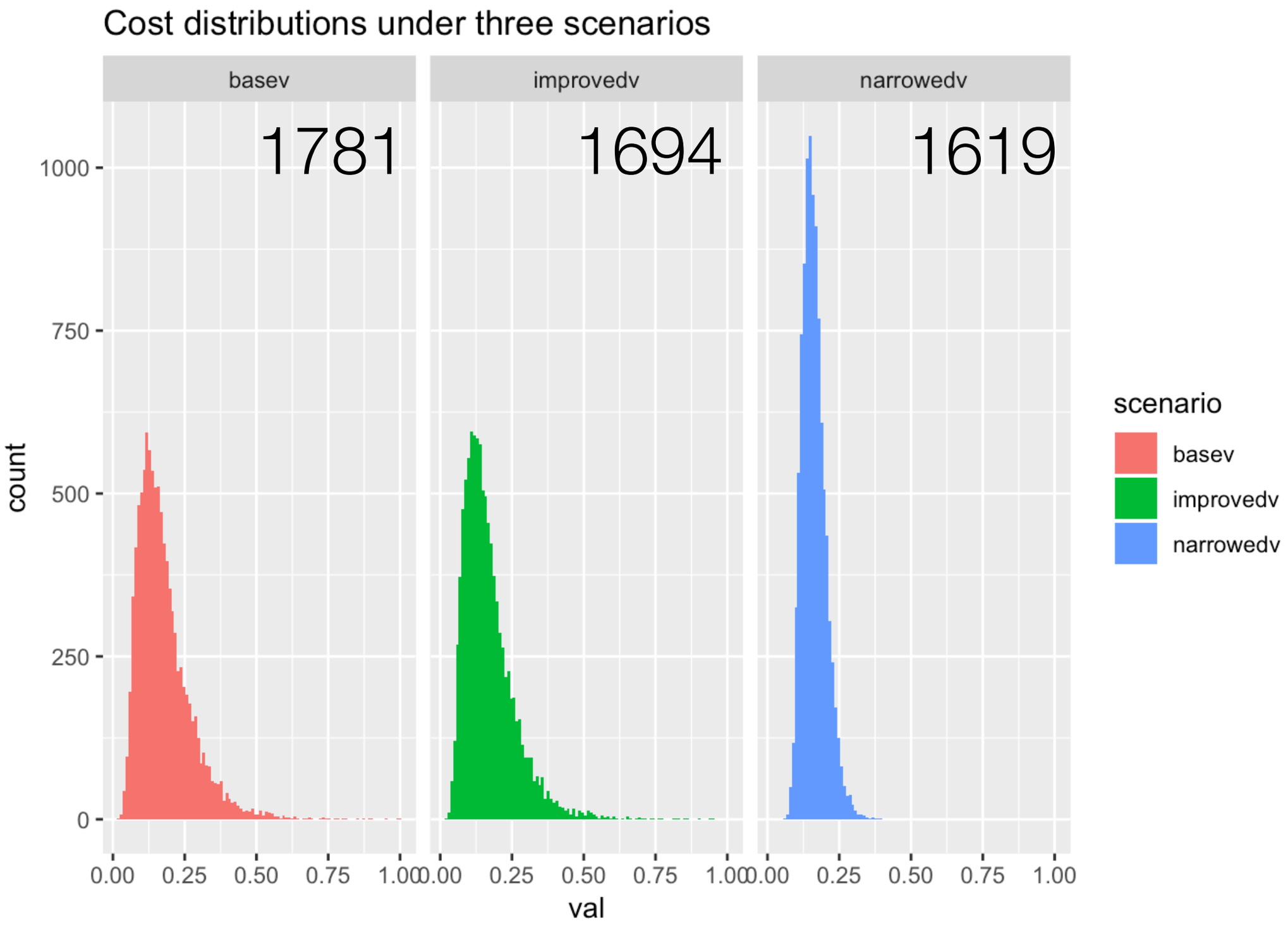
Hypothetical Cost Function



Cost of *n*-th Action Under Three Scenarios



Hypothetical Costs Under Three Scenarios



Where to Find Guidelines

- AHRQ's National Guideline Clearinghouse
  - Since 1997, but shut down by current administration in July 2018
- Guideline Central (https://www.guidelinecentral.com), ~2K guidelines
  - Assessment of Therapeutic Effectiveness
  - Counseling
  - Diagnosis
  - Evaluation
  - Management
  - Prevention
  - Rehabilitation
  - Risk Assessment
  - Screening
  - Technology Assessment
  - Treatment

Example Guidelines from GuidelineCentral

Assessment and Therapeutic Effectiveness	Calculators
Risk reduction of prostate cancer with drugs or nutritional supplements	4Ts Score for Heparin-Induced Thrombocytopenia
Stem cell transplantation in multiple myeloma	A-a O2 Gradient (need for massive transfusion in trauma)
Stem cell transplantation in myelodysplastic syndromes and acute myeloid leukemia	ABCD2 Score for TIA (risk of stroke after a TIA)
Stem cell transplantation in primary systemic amyloidosis	ACR-EULAR Gout Classification Criteria
The role of liver resection in colorectal cancer metastases	ADAPT Protocol for Cardiac Event (2-hours risk of cardiac event for chest pain)
Optimal chemotherapy for recurrent ovarian cancer	APACHE II Score (ICU mortality)
Radionuclide therapy for neuroendocrine malignancies	APGAR Score (neonates 1 and 5 minutes after birth)

https://www.guidelinecentral.com/summaries/#link=https://www.guidelinecentral.com/summaries/categories/assessment-of-therapeutic-effectiveness/&activeTab=#summary-view-category

https://www.guidelinecentral.com/calculators/

Top-Down vs. Bottom-Up

- Guidelines
  - Typically developed by “learned societies”, usually MDs
  - Choice based on clinical importance, controversy, “pet” ideas, …
- Care Plans
  - Individualized to specific patient
  - Developed by nurse taking care of that patient
- Clinical Pathways
  - Generalization of Care Plans
  - Typically developed by hospitals, combining multidisciplinary sources
    - Guidelines, Nursing experience, Clinical Trials, …
  - Choice based on need to standardize care locally, sometimes in response to errors

Sample Adequate Nursing Care Plan (2 pages)
Work of 2nd Semester Junior Nursing Student

Assessment	Nursing Diagnosis	Patient Outcomes	Interventions	Rationale	Evaluation of Outcomes
Objective Data: -Gangrene infected left foot -Open wound -Wet to dry dressing -Pain upon movement, grimacing, shaking -She immediately requests Morphine -She needs assistance when ambulating-even to sit up in bed	#1: Impaired tissue integrity r/t wound, presence of infection.	Patient will: 1. Report any altered sensation or pain at site of tissue impairment during January 23 and 24. 2. Demonstrate understanding of plan to heal tissue and prevent injury by 1/24. 3. Describe measures to protect and heal the tissue, including wound care by 1/24. 4. Experience a wound that decreases in size and has increased granulation tissue. 5. Achieve functional pain goal of zero by 1/24 per patient's verbalizations.	1. Monitor color, temp, edema, moisture, and appearance of surrounding skin; note any characteristics of any drainage. 2. Monitor site of impaired tissue integrity at least once daily for signs of infection. Determine whether patient is experiencing changes in sensation or pain. Pay attention to all high risk areas such as bony prominences, skin folds, and heels. 3. Monitor status of skin around the wound. Monitor patient's skin care practices, noting type of soap or other cleansing agents used, temp of water, and frequency of cleansing. 4. Select a topical treatment that maintains a moist wound – healing environment but also allows absorption of exudate and filling of dead space. 5. Assess patient's nutritional status; refer to nutritional consultation.	1. Systematic inspection can identify possible problem areas early in infection. 2. Pain secondary to dressing change can be managed by interventions aimed at reducing trauma and other sources of wound pain. 3. Individualize the plan according to patient's skin condition needs and preferences. Avoid harsh cleaning agents, hot water, extreme friction or force, and too frequent cleansing. 4. Choose dressings that provide moist environment, keep skin around wound dry and control exudate and eliminate dead space. 5. A good diet with nutritional foods and vitamins may help promote wound healing.	1. Surrounding skin remained intact and w/ o inflammation. 2. Wound did not have signs of added infection. 3. Educated patient on technique of cleansing and putting on dressing. Had her watch while I did it so she could understand. She stated she would try to do it herself when she is discharged. 4. Used wet to dry dressing, which was changed twice a day. 5. She was on a clear fluid diet but still has little appetite. Continued consultation with nutritionist before discharge would be beneficial.
Subjective Data: -Patient said the pain is worse when ambulating & turning -She said she dreads physical therapy -She said she wishes she did not have to be in this situation					
Medical Diagnoses: -Diabetes foot ulcer -Diabetes Mellitus Type 2 -PVD -Infection					

Typical Care Plans

Care Plans
Activities Care Plan
Admission Care Plan
Adult Failure to Thrive Care Plan
Alcohol Withdrawal Care Plan
Allergic Rhinitis Care Plan
Altered Cardiac Output Care Plan
Amputation Care Plan
Anasarca Care Plan
Anemia Care Plan
Angina Care Plan
Anticoagulant Care Plan
Aphasia Care Plan
Arthritis Care Plan
Asthma Management Plan for School Nurse
Behavior Problem Care Plan
Benign Prostate Hypertrophy Care Plan
Breast Feeding Careplan
Cancer Care Plan
Cardiomegaly Care Plan
Cellulitis
Cerebral Palsy Care Plan

https://www.careplans.com/pages/lib/default.aspx?cid=6

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Paving the COWpath: Learning and visualizing clinical pathways from electronic health record data

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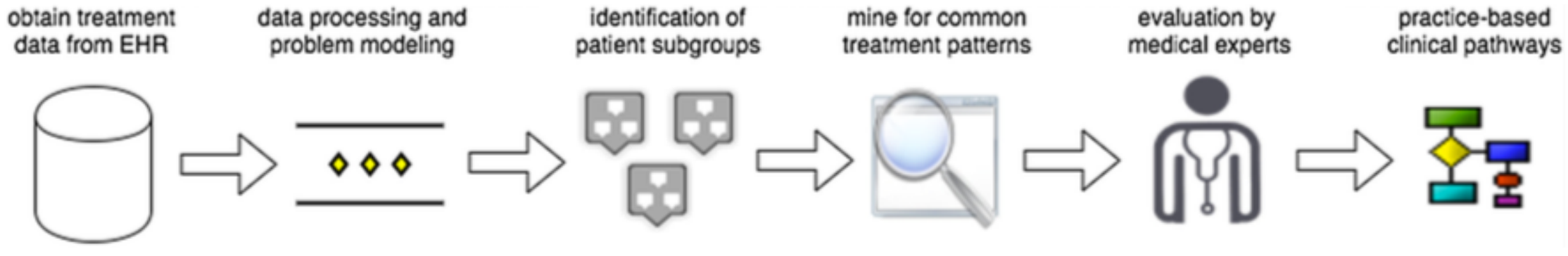
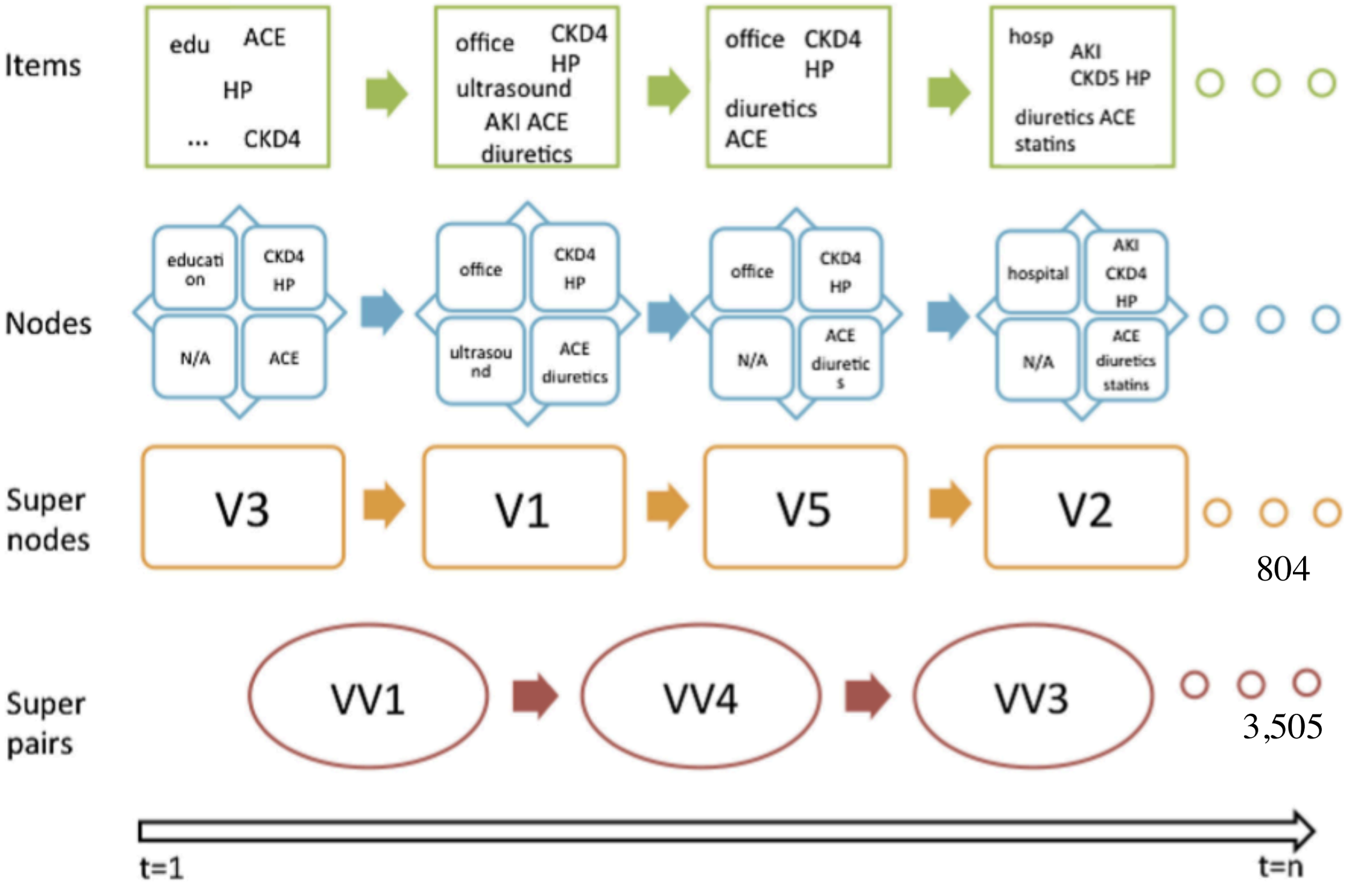


Fig. 1. Practice-based clinical pathway development process.

Mining Clinical Pathways: Representation

- An *event* is a visit, with a purpose and sets of:
  - procedures,
  - medications: {Angiotensin converting enzyme (ACE) inhibitors, Angiotensin receptor blockers (ARB), diuretics, and statins
  - diagnoses: {CKD stage 1 to stage 5, AKI, hypertension, diabetes, end stage renal disease (ESRD)}
- These events are abstracted into *supernodes*
  - each captures a unique combination of events associated with some visit
- Each patient then has a *visit sequence*, a time-ordered list of supernodes describing successive visits
- To support a two-step Markov analysis, aggregate visits into *super pairs* of two successive supernodes.

Visit History as a Markov Chain



Mining Clinical Pathways: Clustering

- Computer max of the length of common subsequences between each pair of visit sequences
- dist(x, y) = |x| + |y| - 2 LCS(x, y)
- hierarchic clustering into distinct subgroups (31, in their case)

Subgroup Clusters

clustering by trajectory, but these are the most common supernodes in the cluster

Table 5
Summary statistics across patient subgroups.

Sub group	# Patients	Visit content with the highest support			
		Purpose	Diagnoses	Drug Class	Support
1	80	Office	CKD stage 3, diabetes, hypertension	–	0.54
2	16			ACE	1
3	55			ACE, ARB, diuretics, statins	0.78
4	122			ACE, diuretics, statins	0.7
5	21			ACE, statins	1
6	10			ARB	1
7	36			ARB, diuretics	0.75
8	22			ARB, statins	0.95
9	74			Diuretics	0.69
10	83			Diuretics, statins	0.84
11	75			Statins	0.63
12	158		CKD stage 3, hypertension	–	0.52
13	29			ACE	0.72
14	66			ACE, diuretics, statins	0.77
15	14			ACE, ARB, diuretics	0.86
16	32			ACE, diuretics	0.69
17	26			ACE, statins	0.96
18	14			ARB	0.93
19	19			ARB, diuretics	0.95
20	20			ARB, statins	0.95
21	86			Diuretics	0.57
22	100			Diuretics, statins	0.59
23	68			Statins	0.71
24	90		CKD stage 3/4, diabetes, hypertension	ARB, diuretics, statins	0.67
25	38		CKD stage 3/4, hypertension	ARB, diuretics, statins	0.6
26	18		CKD stage 4, diabetes, hypertension	ACE, diuretics	0.67
27	14			ACE, statins	1
28	69			Diuretics, statins	0.94
29	14		CKD stage 4, hypertension	ACE, statins	1
30	29	Hospital	AKI, CKD stage 3	–	0.55
31	78	Deceased			0.15

1,576 patients, 17,358 visits

(Partial) Transition Matrix

(pathways depend on thresholds chosen)

P_{ij}, C_{ij}		Second Visit				
		VV1	VV2	VV3	VV4	VV5
First Visit	VV1	0, 0	1, 8	0, 0	0, 0	0, 0
	VV2	0, 0	0, 0	0.4, 8	0.6, 12	0, 0
	VV3	0.1, 1	0.1, 1	0.2, 2	0.1, 1	0.5, 5
	VV4	0, 0	0, 0	1, 5	0, 0	0, 0
	VV5	0.2, 4	0.3, 6	0.1, 2	0.2, 4	0.2, 4

Fig. 4. Extraction of clinical pathways using Markov chain transition matrix.

Transitions for Cluster 29

({CKD stage 4, hypertension}, {ACE, statins}) n=14 (!)

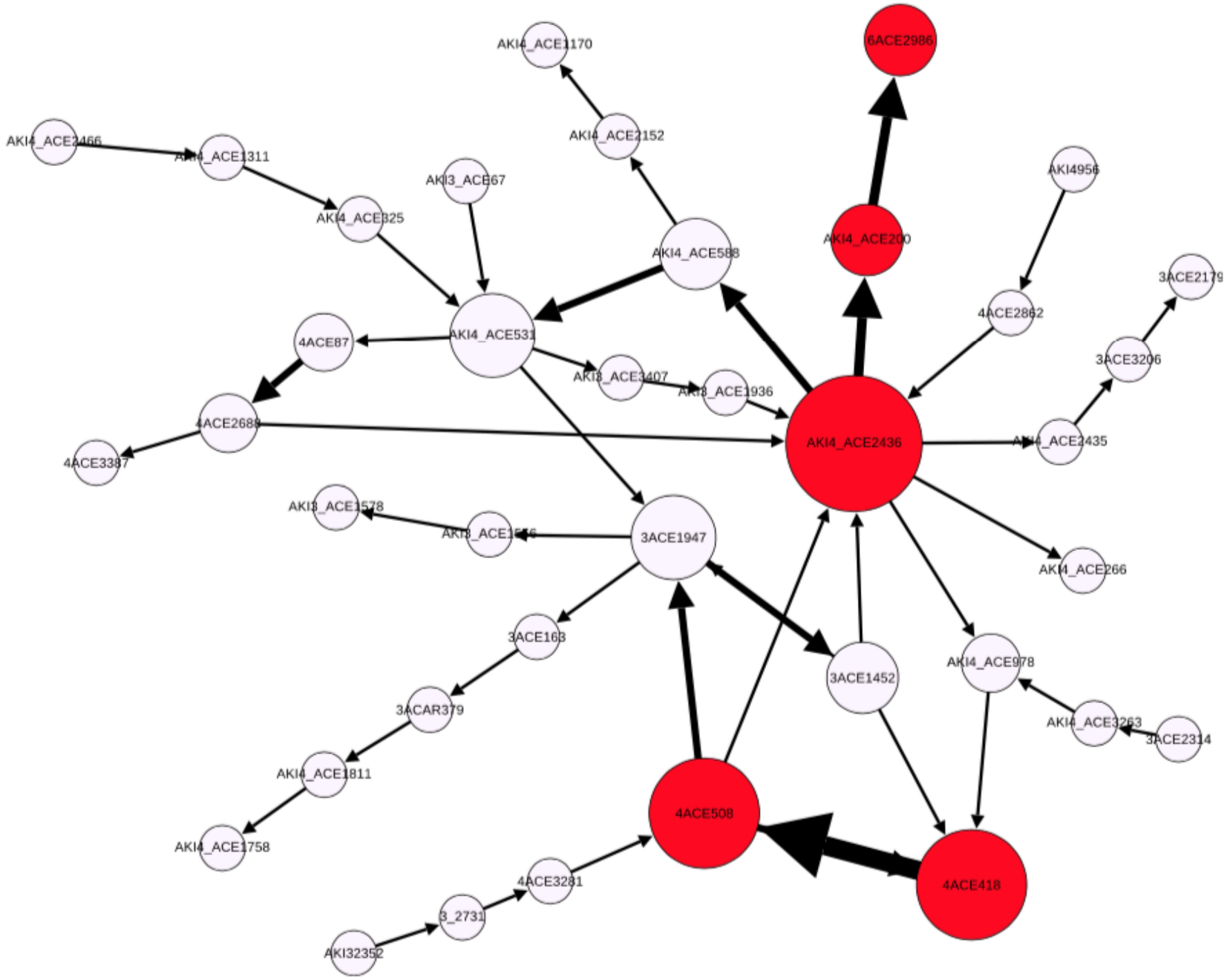


Fig. 7. Clinical pathway mined for subgroup 29.

Transitions for Cluster 29: interpreted, common

({CKD stage 4, hypertension}, {ACE, statins})

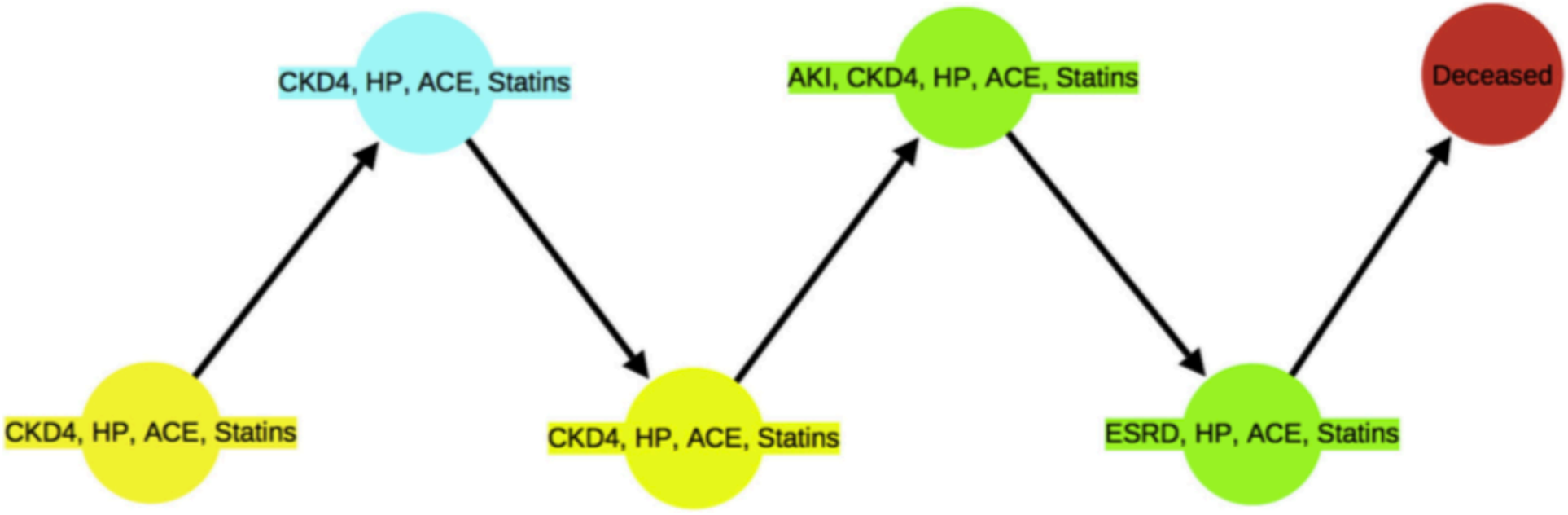


Fig. 8. Visualization of a clinical pathway for patients in subgroup 29. Yellow node: office visit, green node: hospitalization, blue: education visit, red: deceased, CKD4: CKD stage 4, HP: hypertension. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

How Useful is This?

- Many subgroups, with 10–158 samples
- Limited data about each visit
  - e.g., no labs, few diagnoses and medication classes
- Complex transition graphs need human interpretation
- Models what *is* done, not what *should be* done
  - (but this is a common problem)

Other Workflow Issues

- Alerting
  - Escalation of alerts on non-response
  - BIDMC study of unread messages in Patient Portal (only ~3%)
- Importance of Communication
- Integration of all data sources
  - Failure of Google Health, Microsoft Health Vault, …

Lab Alerts

- Beth Israel experience, 1994
  - rising creatinine levels while taking nephrotoxic or renally excreted drugs
  - 21.6 hour reduction in reaction time
  - risk or renal impairment reduced to 0.45 of pre-intervention level
  - 44% of docs found them helpful, 28% found them annoying, 65% wanted them continued

Rind, D., Safran, C., Phillips, R. S., Wang, Q., Calkins, D. R., Delbanco, T. L., et al. (1994). Effect of computer-based alerts on the treatment and outcomes of hospitalized patients. Archives of Internal Medicine, 154(13), 1511–1517.

The communication space

- is the largest part of the health system's information space
- contains a substantial proportion of the health system information 'pathology'
- is largely ignored in our informatics thinking
- is where most data is acquired and presented

How big is the communication space?

- Covell et al. (1985): 50% info requests are to colleagues, 26% personal notes
- Tang et al (1996): talk is 60% in clinic
- Coiera and Tombs (1996,1998): 100% of non-patient record information
- Safran et al. (1998): ~50% face to face, EMR ~10%, e/v-mail and paper remainder

What happens in the communication space?

- Wilson et al. (1995): communication errors commonest cause of in-hospital disability/death in 14,000 patient series
- Bhasale et al. (1998): contributes to ~50% adverse events in primary care
- Coiera and Tombs (1998): interrupt-driven workplace, poor systems and poor practice

Coiera, E., & Tombs, V. (1998). Communication behaviours in a hospital setting: an observational study. BMJ (Clinical Research Ed), 316(7132), 673–676.

No of call events (No of successful connections) categorised by subject and call type among 10 hospital staff

	Page call		Telephone call		Length of observation	Total No of events
Subject and role	Sent	Received	Made	Received	(hours: minutes)	
7 (consultant)	0	0	0	0	2:55	0
2 (house officer)	0	0	0	0	2:59	0
1 (consultant)	0	0	1 (1)	0	3:15	1 (1)
6 (senior registrar)	0	0	2 (2)	0	2:05	2 (2)
9 (house officer)	3 (0)	3 (3)	6 (6)	0	2:41	12 (9)
8 (nurse)	4 (2)	0	4 (4)	5 (5)	2:09	13 (11)
10 (house officer)	0	2 (2)	11 (10)	0	2:55	13 (12)
5 (senior registrar)	0	4 (4)	10 (7)	0	3:39	14 (11)
3 (nurse)	1 (0)	2 (2)	13 (4)	1 (1)	3:23	17 (7)
4 (senior house officer)	1 (1)	10 (10)	9 (3)	4 (4)	3:39	24 (18)
Total	9 (3)	21 (21)	56 (37)	10 (10)	29:40	96 (71)

ER communication study

- Medical Subject #4
  - 3 hrs 15 min observation
  - 86% time in ‘talk’
  - 31% time taken up with 28 interruptions
  - 25% multi-tasking with 2 or more conversations
  - 87 % face to face, phone, pager
  - 13 % computer, forms, patient notes

Implications

- Clinicians already seem to receive too many messages resulting in:
  - interruption of tasks
  - fragmentation of time, potentially leading to inefficiency
  - potential for forgetting, resulting in errors

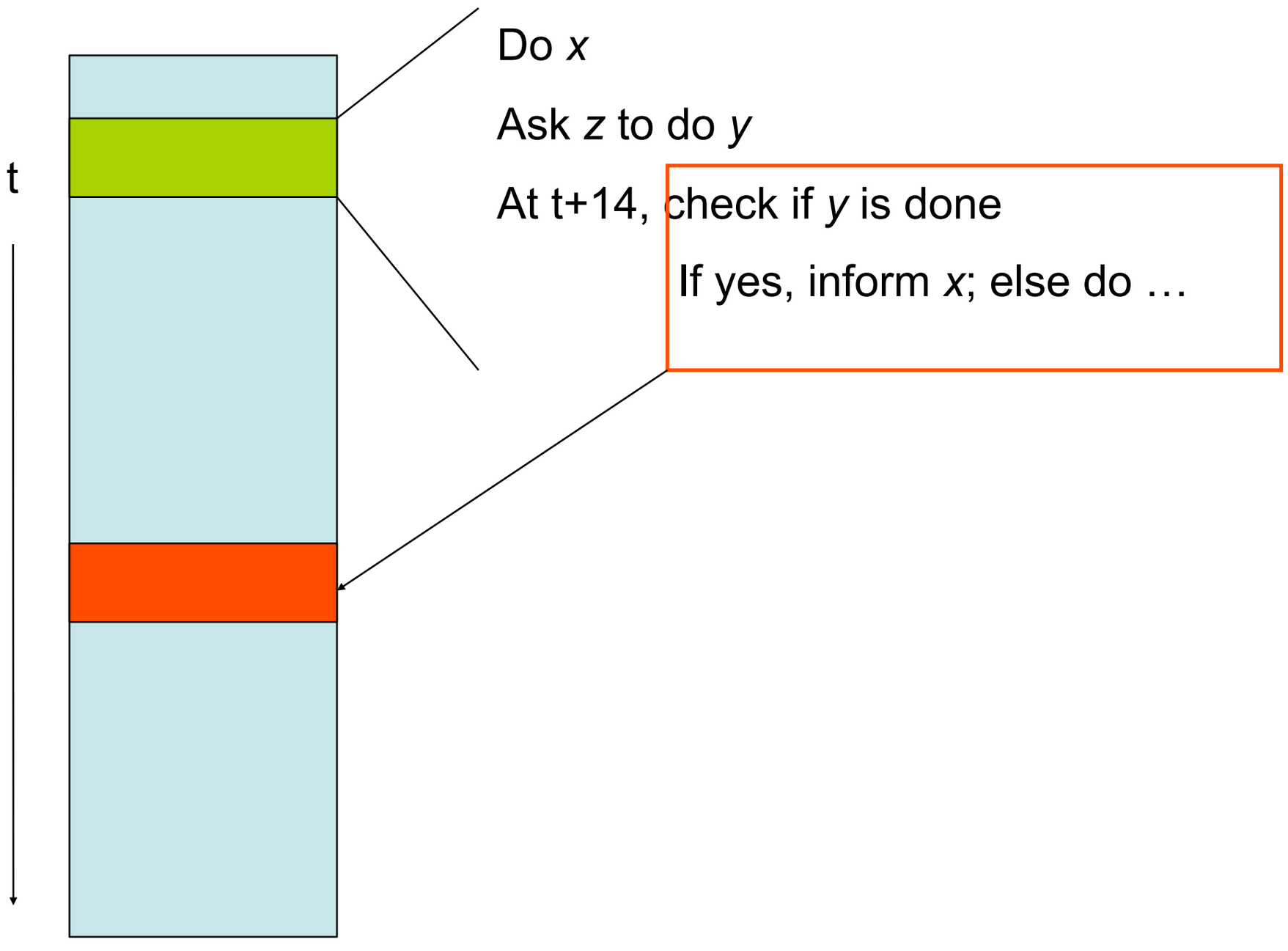
Communication options

- We can introduce new:
  - *Channels,* e.g., v-mail
  - *Types of message,* e.g., alert
  - *Communication policies,* e.g., prohibit sending an e-mail organisation-wide
  - *Communication services,* e.g., role-based call forwarding
  - *Agents* creating or receiving messages, e.g., web-bots for info retrieval
  - *Common ground* between agents, e.g., train team members
- Synchronous:
  - face to face, pager, phone
  - generate an interrupt to receiver
- Asynchronous:
  - post-it notes, e-mail, v-mail
  - receiver elects moment to read

How to keep from dropping the ball?

- Coordination
  - CSP, where some of the processes are people
  - Checking that others are “on track”
- Resource allocation
- Design of rational human-institution-technology systems

Workflow Engine
≈ discrete-event simulator



Google Health: A Personal Health Record

- In 2008, the service underwent a two-month pilot test with 1,600 patients of The Cleveland Clinic
- Starting on May 20, 2008, Google Health was released to the general public as a service in beta test stage
- 2011 Google announced it was retiring Google Health

- Partners: Allscripts, Anvita Health, The Beth Israel Deaconess Medical Center, Blue Cross Blue Shield of Massachusetts, The Cleveland Clinic, CVS Caremark, Drugs.com, Healthgrades, Longs Drugs, Medco Health Solutions, Quest Diagnostics, RxAmerica, and Walgreens
- Other than these partners, no facilities to enter data automatically
- No facilities at all to allow/encourage clinicians to look at these data
  - Missing integration with hospital/clinic EHRs

- Also see “Guardian Angel”, http://ga.org