Lumbar Imaging with Reporting of Epidemiology (LIRE): The Beginning of the End (or The End of the Beginning?)

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- PCORI: CE-12-11-4469

Disclosures (Jarvik)

- Physiosonix (ultrasound company)
  - Founder/stockholder
- Healthhelp (utilization review)
  - Consultant
- Evidence-Based Neuroimaging Diagnosis and Treatment (Springer)
  - Co-Editor

Talk Outline

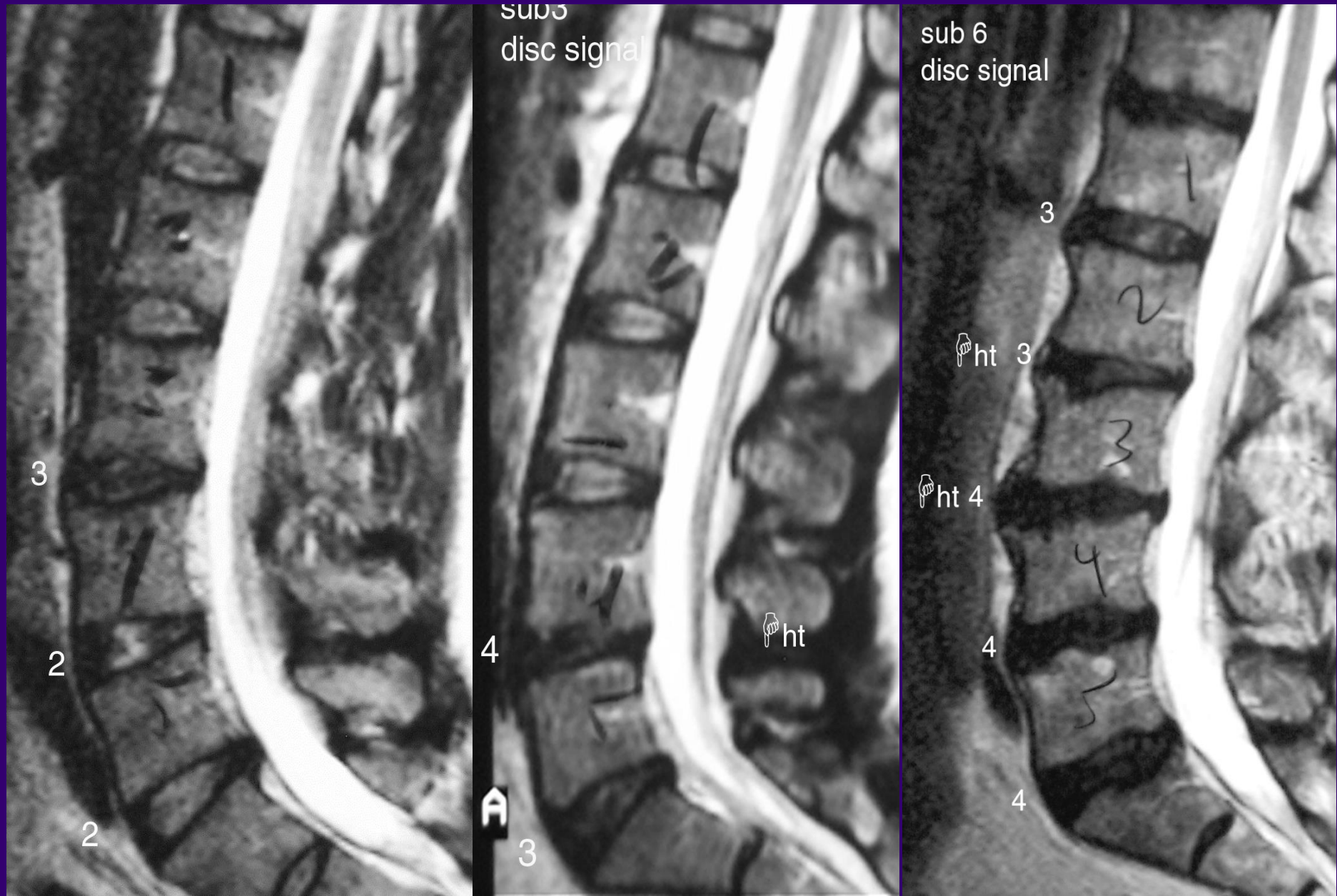
- Brief review of study goals/design
- Progress to date
- NLP for data extraction from radiology reports
- Next steps

LIRE (pronounced leer)- From the French verb, “To Read”

Background and Rationale

- Lumbar spine imaging frequently reveals incidental findings
- These findings may have an adverse effect on:
  - Subsequent healthcare utilization
  - Pt health related quality of life

Disc Degeneration in Asx

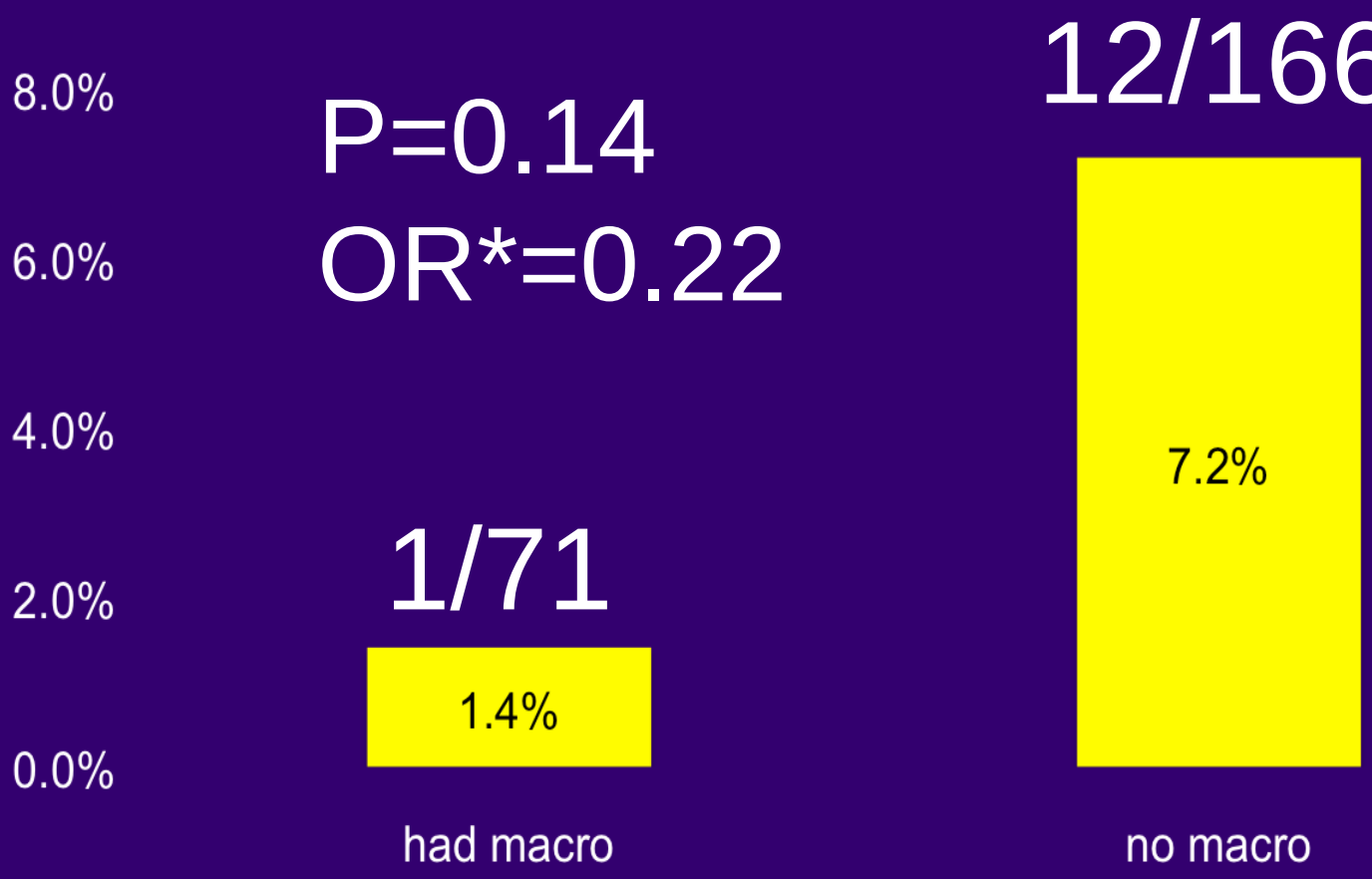



EDNA'S DOCTOR FANTASY
There's something I've been meaning to tell you.
You are the healthiest person I've ever seen.
Don't even bother coming back!

Hypothesis

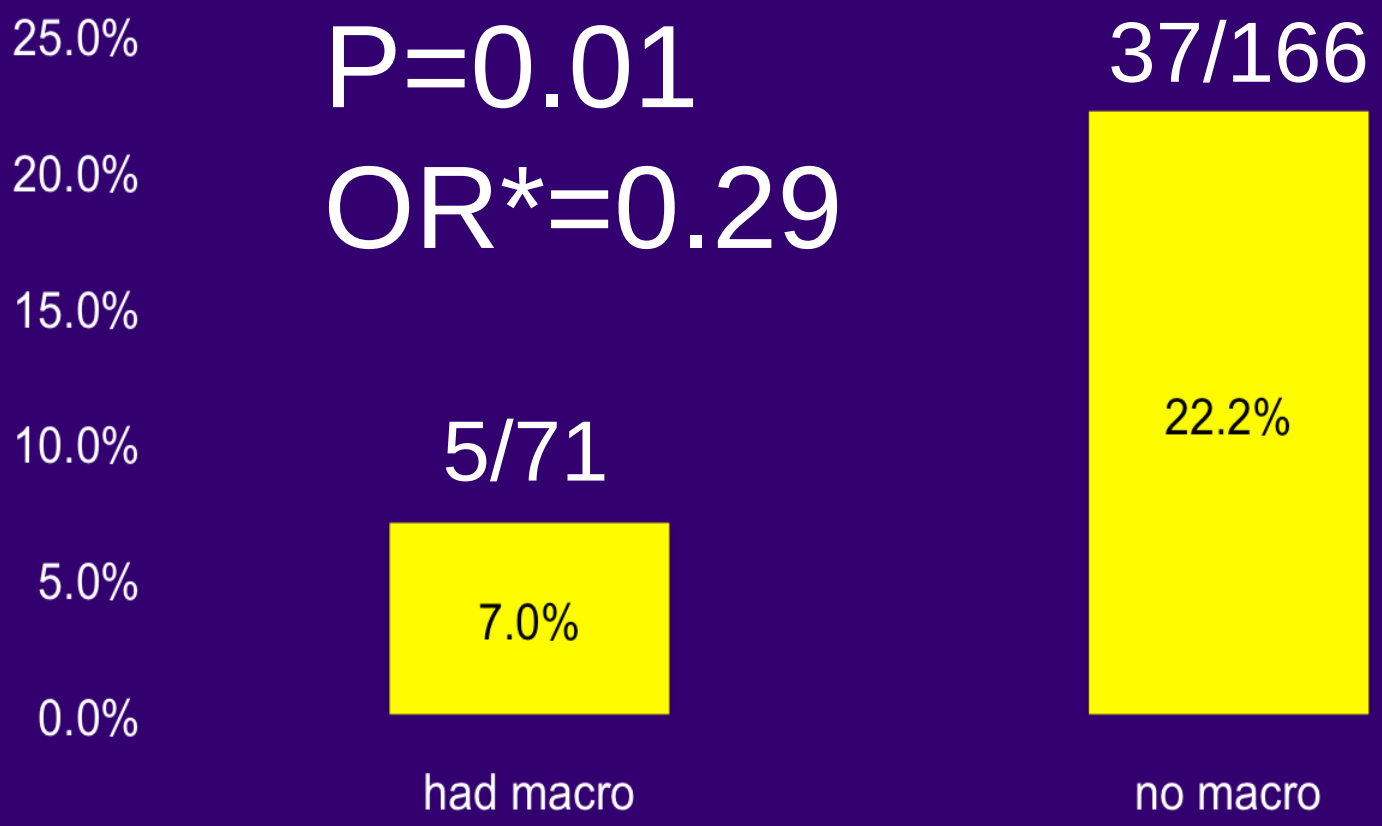
- For pts referred from primary care, inserting prevalence benchmark data in lumbar spine imaging reports will reduce:
  - subsequent x-sectional imaging (MR/CT)
  - opioid prescriptions
  - spinal injections
  - surgery

Retrospective Pilot Results: Subsequent Imaging Within 1 Yr



* Adjusted for imaging severity

Retrospective Pilot Results: Narcotic Rx Within 1 Yr



Intervention Text

The following findings are so common in normal, pain-free volunteers, that while we report their presence, they must be interpreted with caution and in the context of the clinical situation. Among people between the age of 40 and 60 years, who do not have back pain, a plain film x-ray will find that about:

- 8 in 10 have disk degeneration
- 6 in 10 have disk height loss

Note that even 3 in 10 means that the finding is quite common in people without back pain.

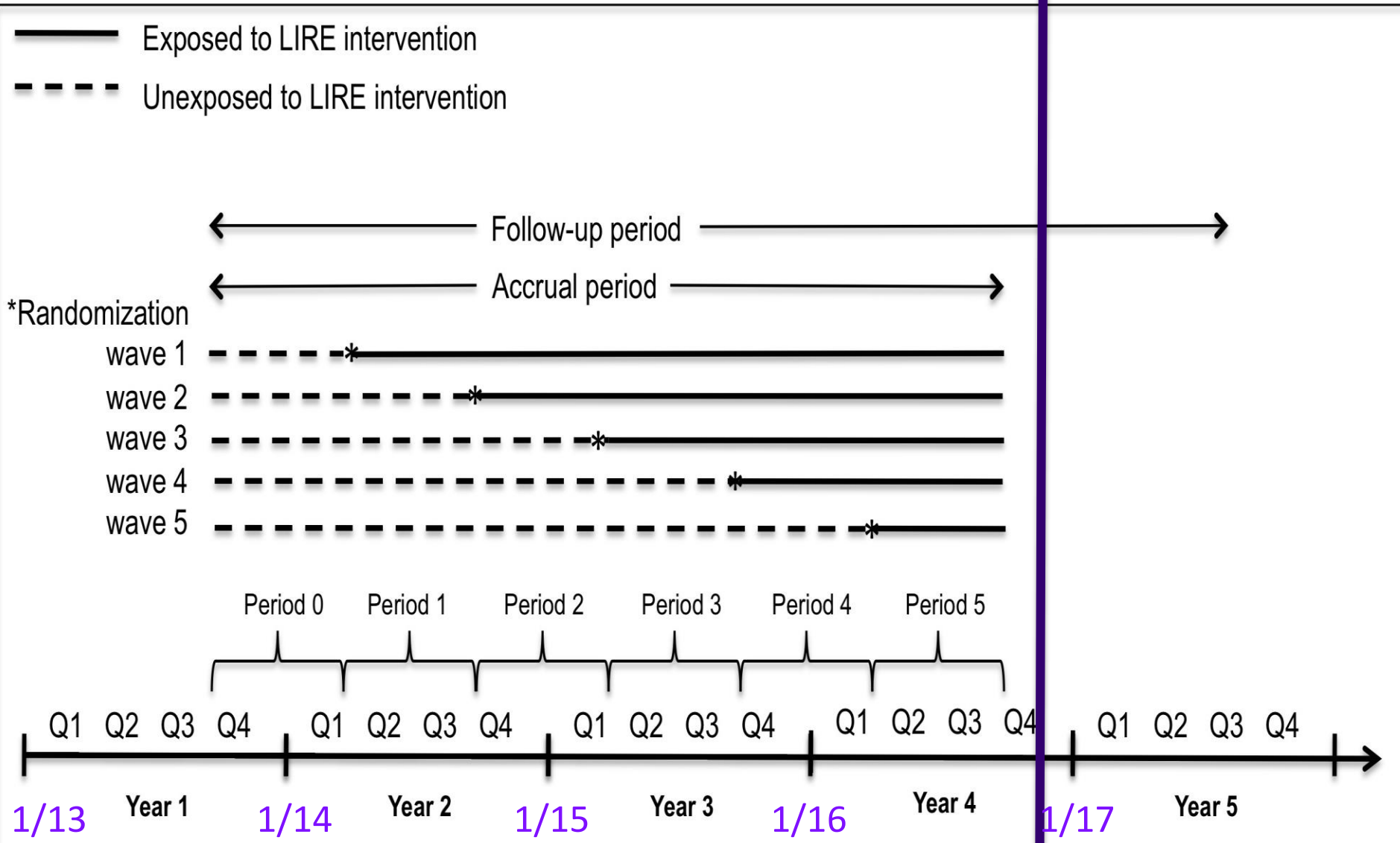
Randomization

- Cluster (clinic)
- Stepped wedge (one way crossover)

Participating Systems

Name	# Primary Care Clinics (Original)	# Primary Care Clinics (Randomized)	# PCPs (Original)	# PCPs (Randomized)
Kaiser Perm. N. California	17	21	1,006	2,243
Henry Ford Health System, MI	26	26	230	187
Group Health Coop of Puget Sound	25	19	303	365
Mayo Health System	61	34	269	400
Total	129	100	1808	3,195

Stepped Wedge RCT



LIRE- The Outcome

- A single metric of overall intensity of resource utilization for spine care based on CPTs converted to RVUs
- Passively collected from EHR

Key Pragmatic Aspects of LIRE

- Broad inclusion criteria
- Waiver of consent
- Centralization of IRB review
- Simple, easily implemented intervention
- Passive collection of outcomes
- Cluster randomization
- Stepped wedge randomization

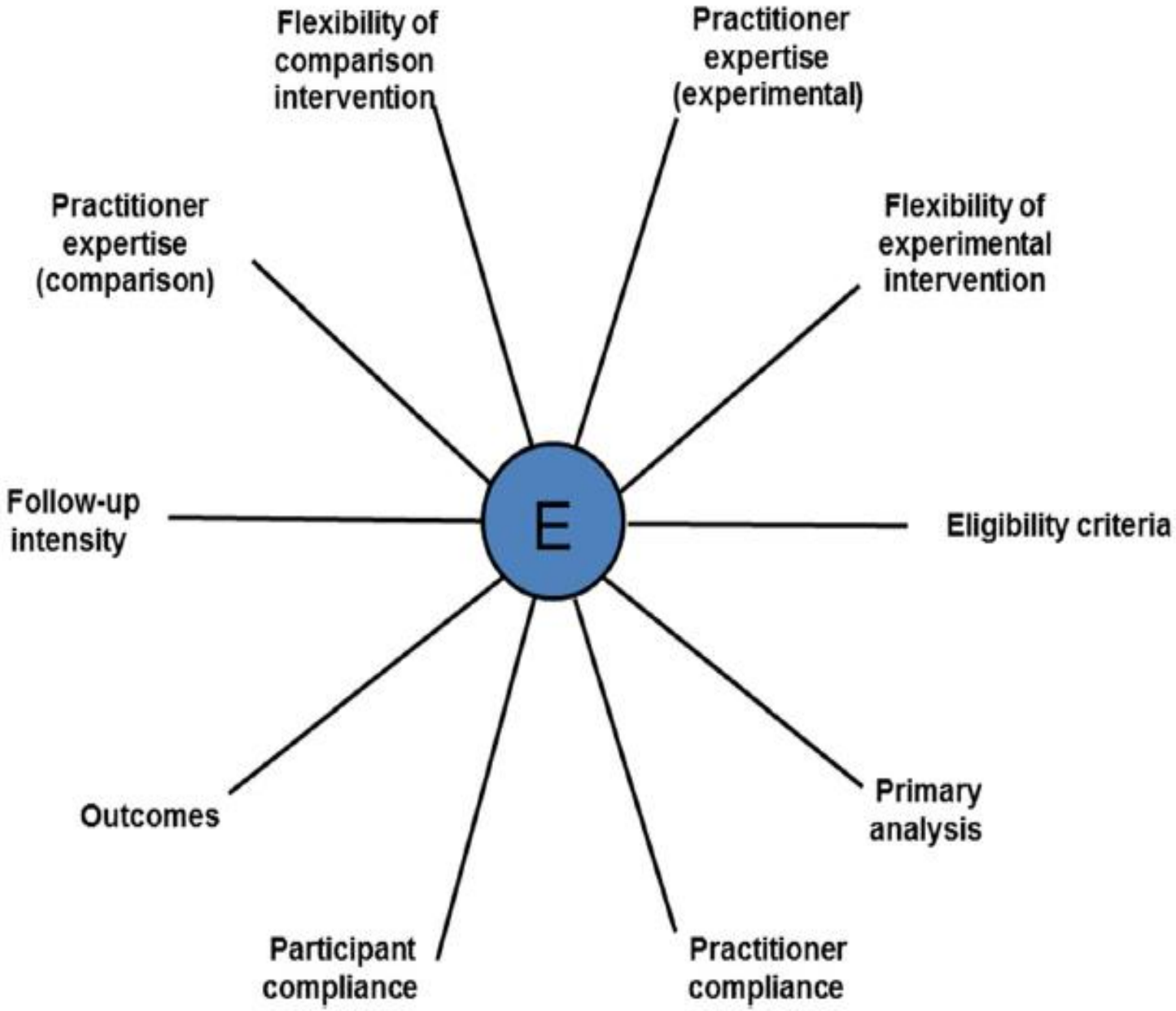
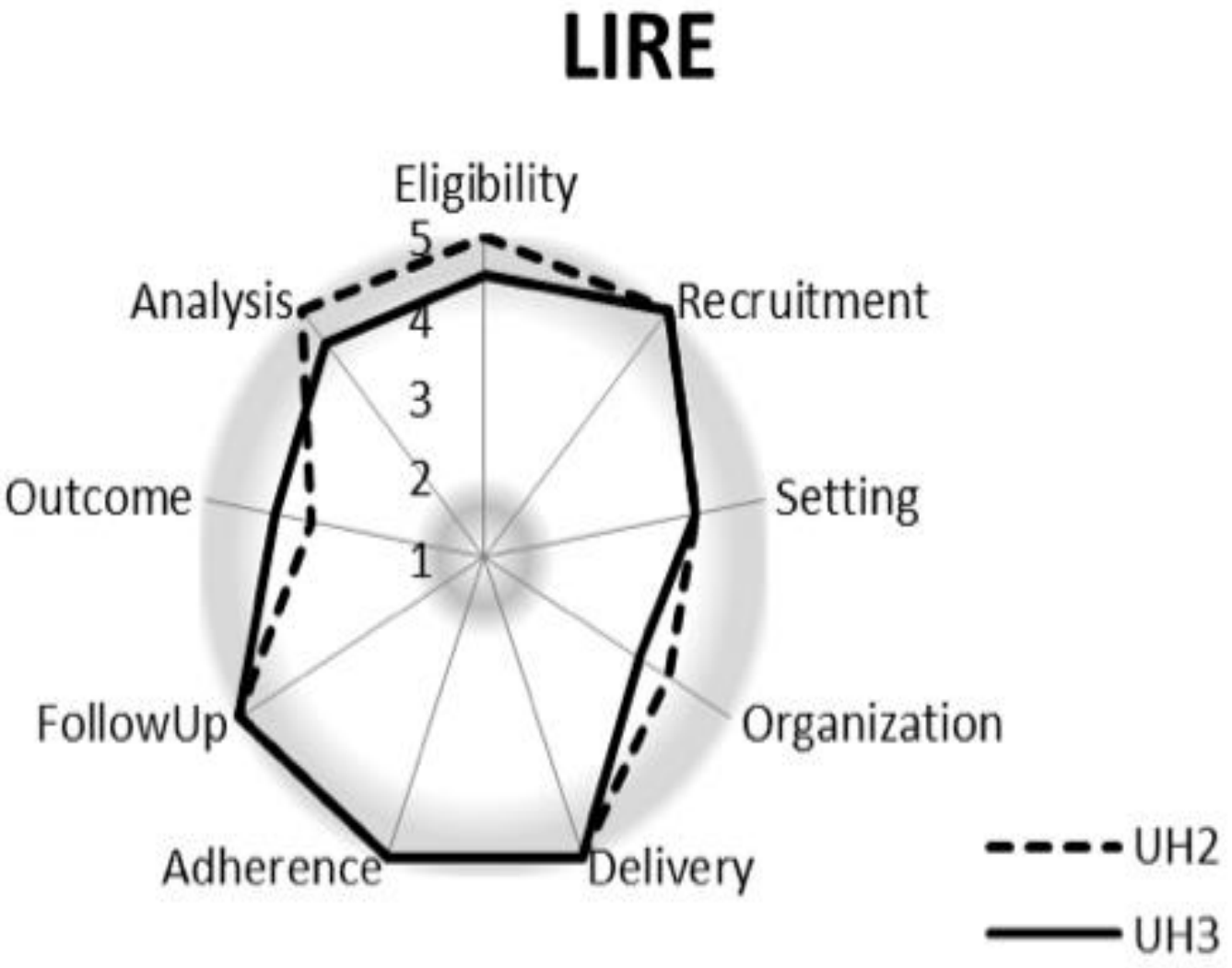


Figure 1 Pragmatic Explanatory Continuum Indicator Summary (PRECIS) [10].

LIRE PRECIS


LIRE
Eligibility
5
4
3
2
1
Recruitment
Setting
Organization
Delivery
Adherence
FollowUp
Outcome
Analysis
UH2
UH3

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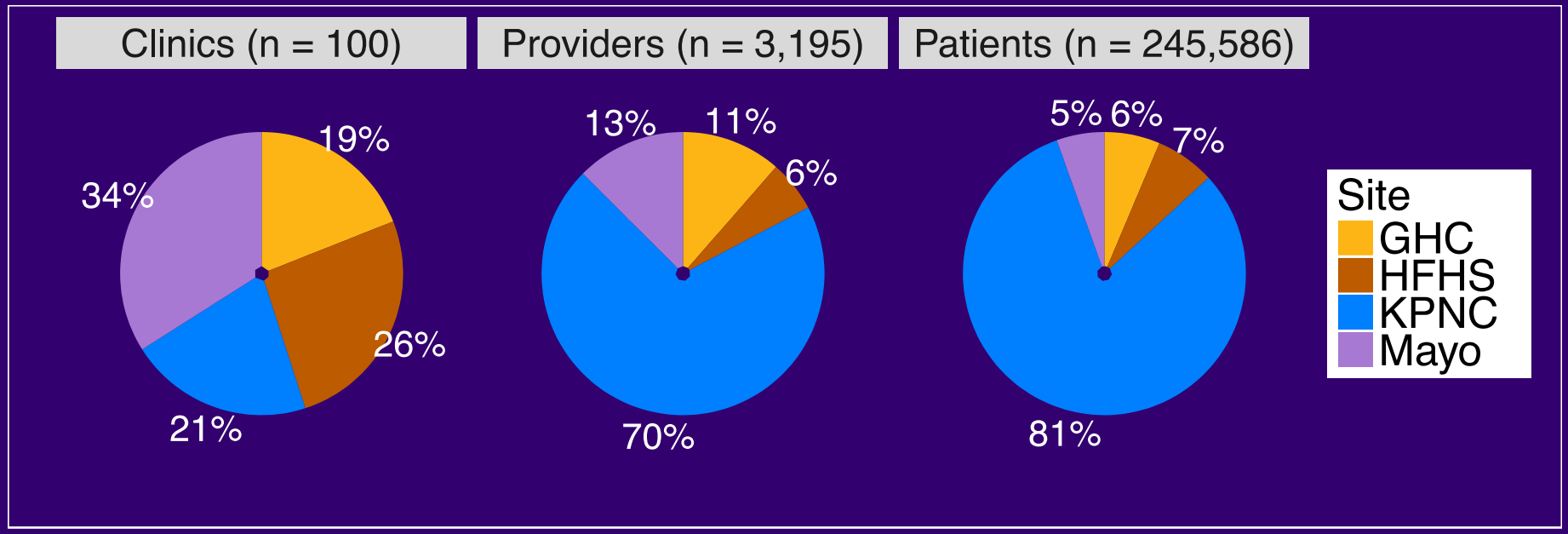
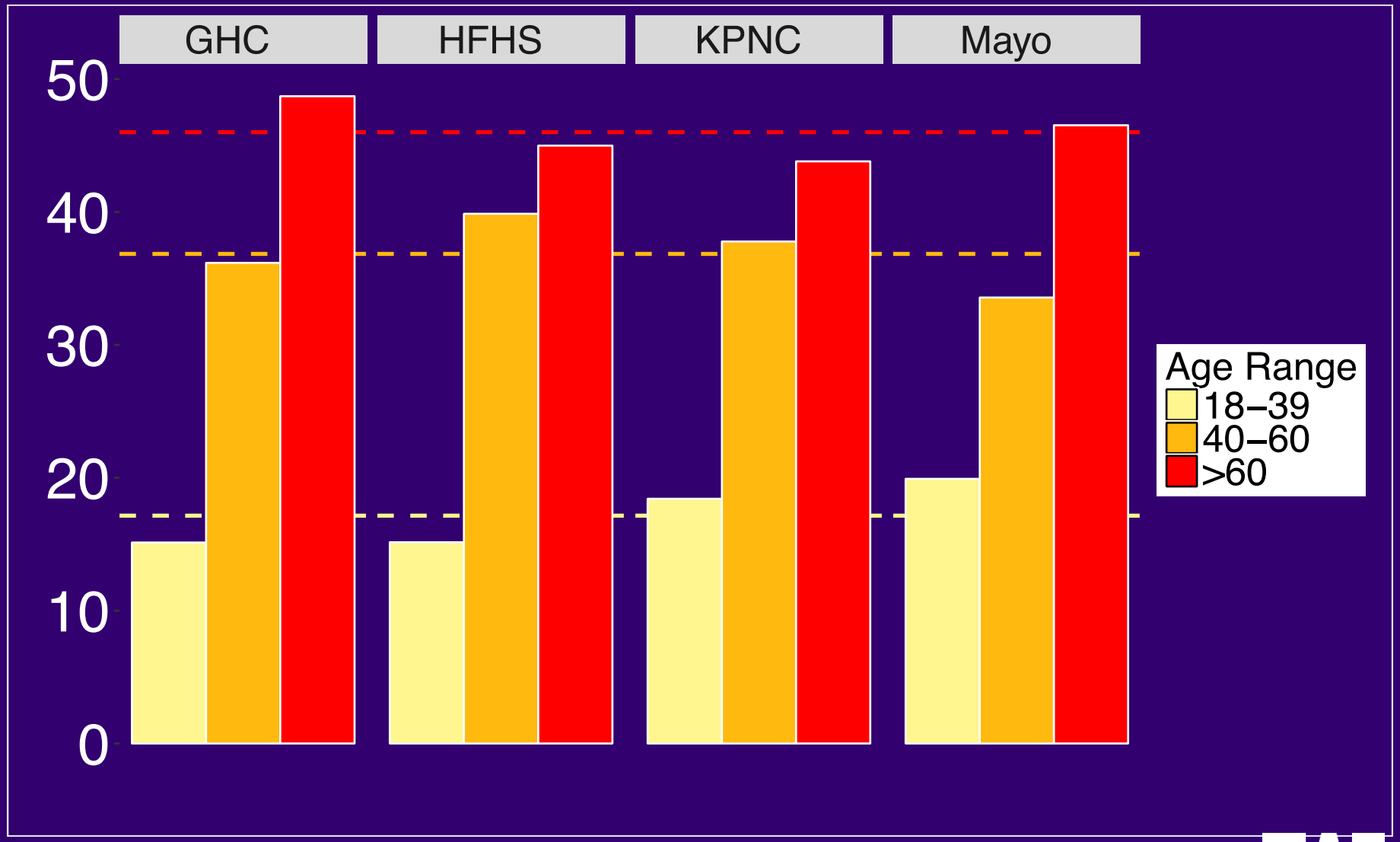
LIRE: Enrollment

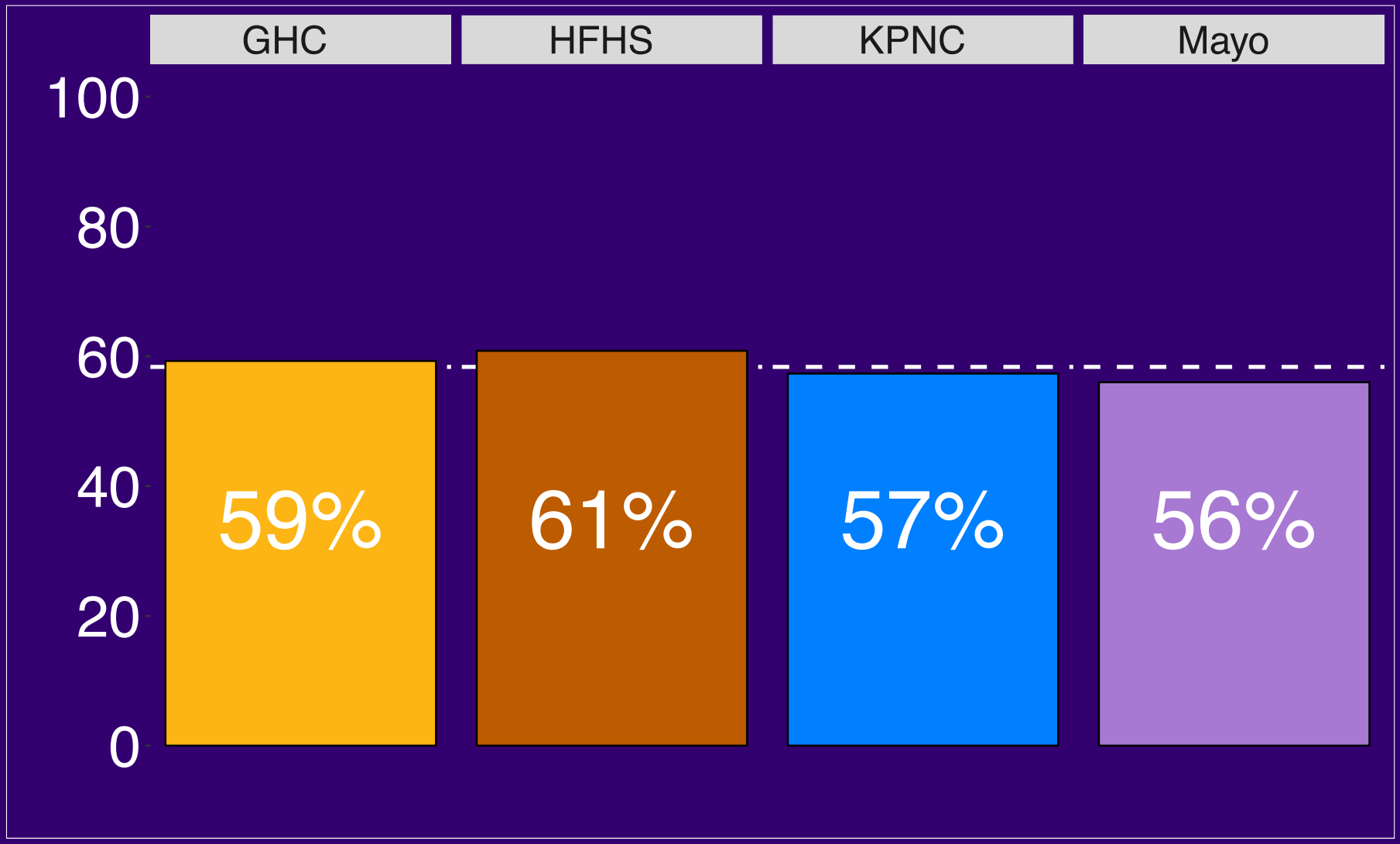


Demographics

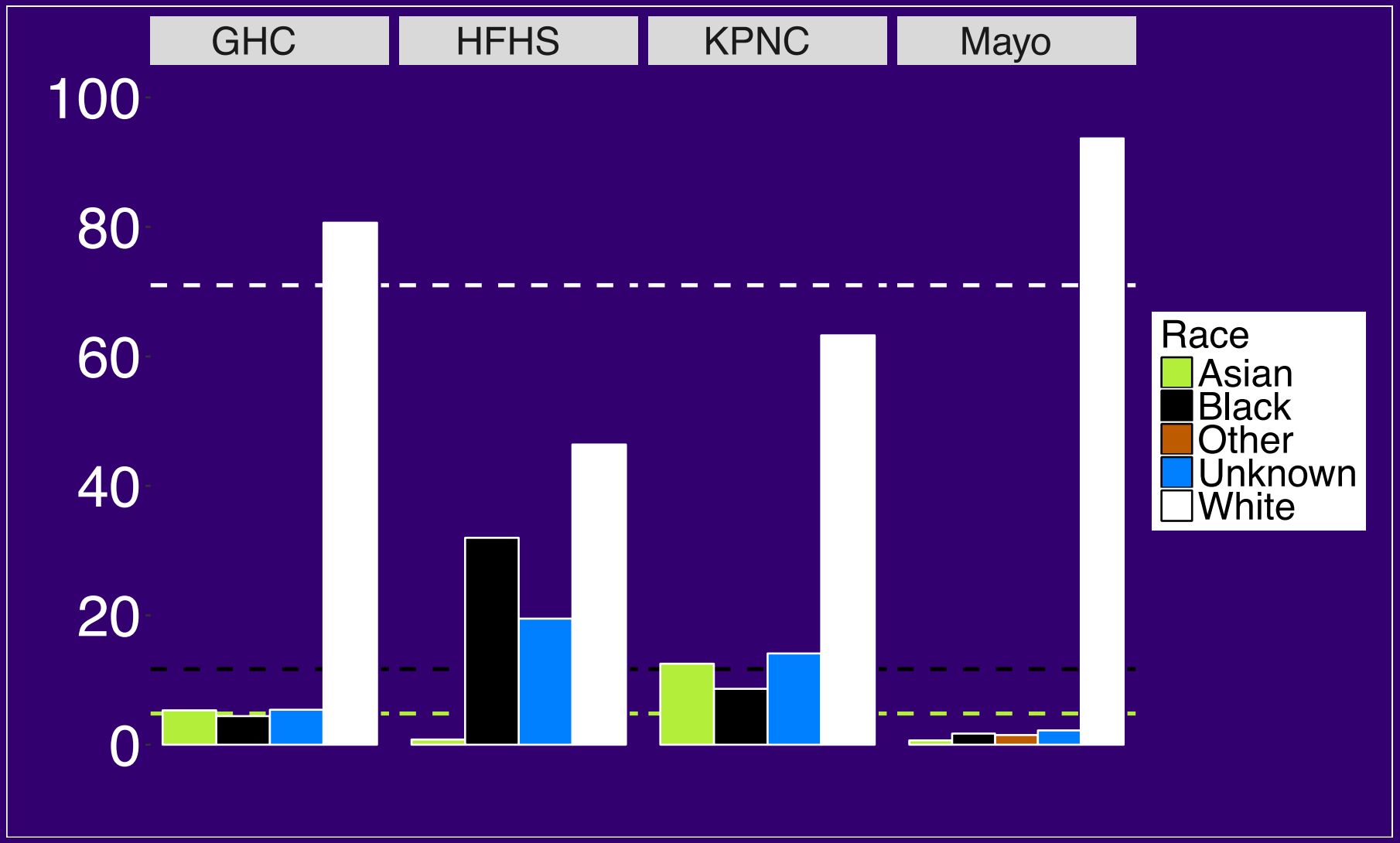
Patient age at index image



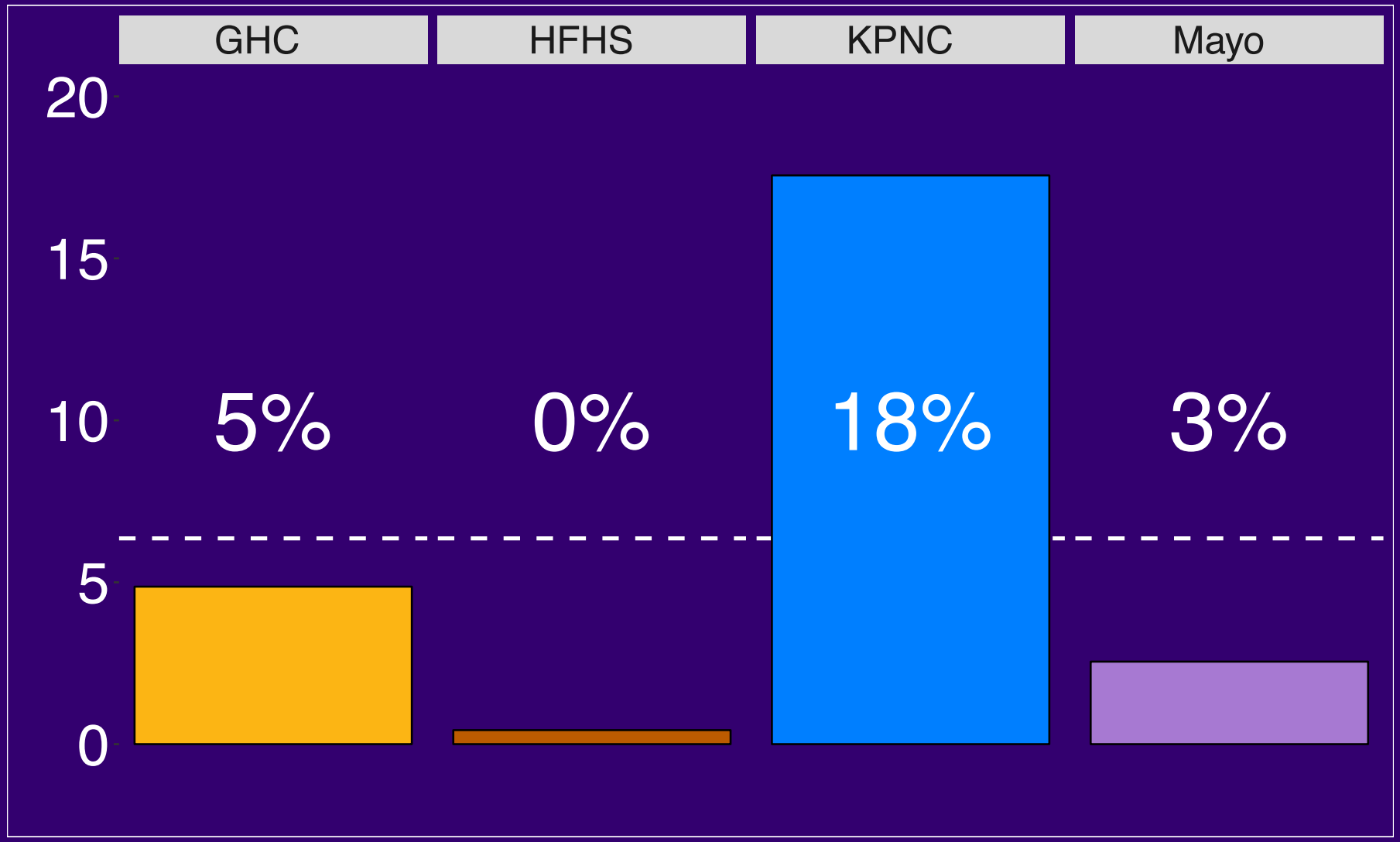
Female



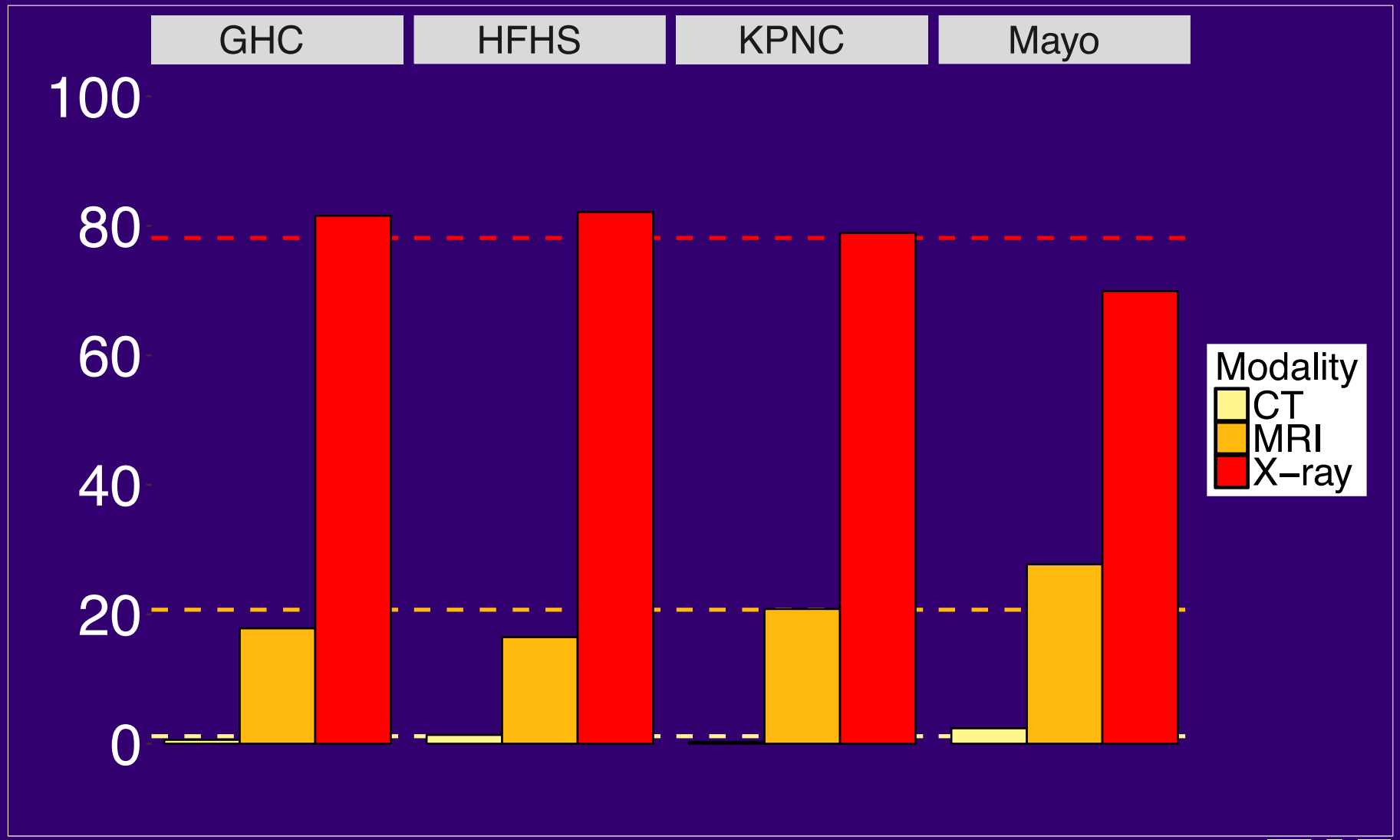
Race


GHC
HFHS
KPNC
Mayo
100
80
60
40
20
0
Race
Asian
Black
Other
Unknown
White

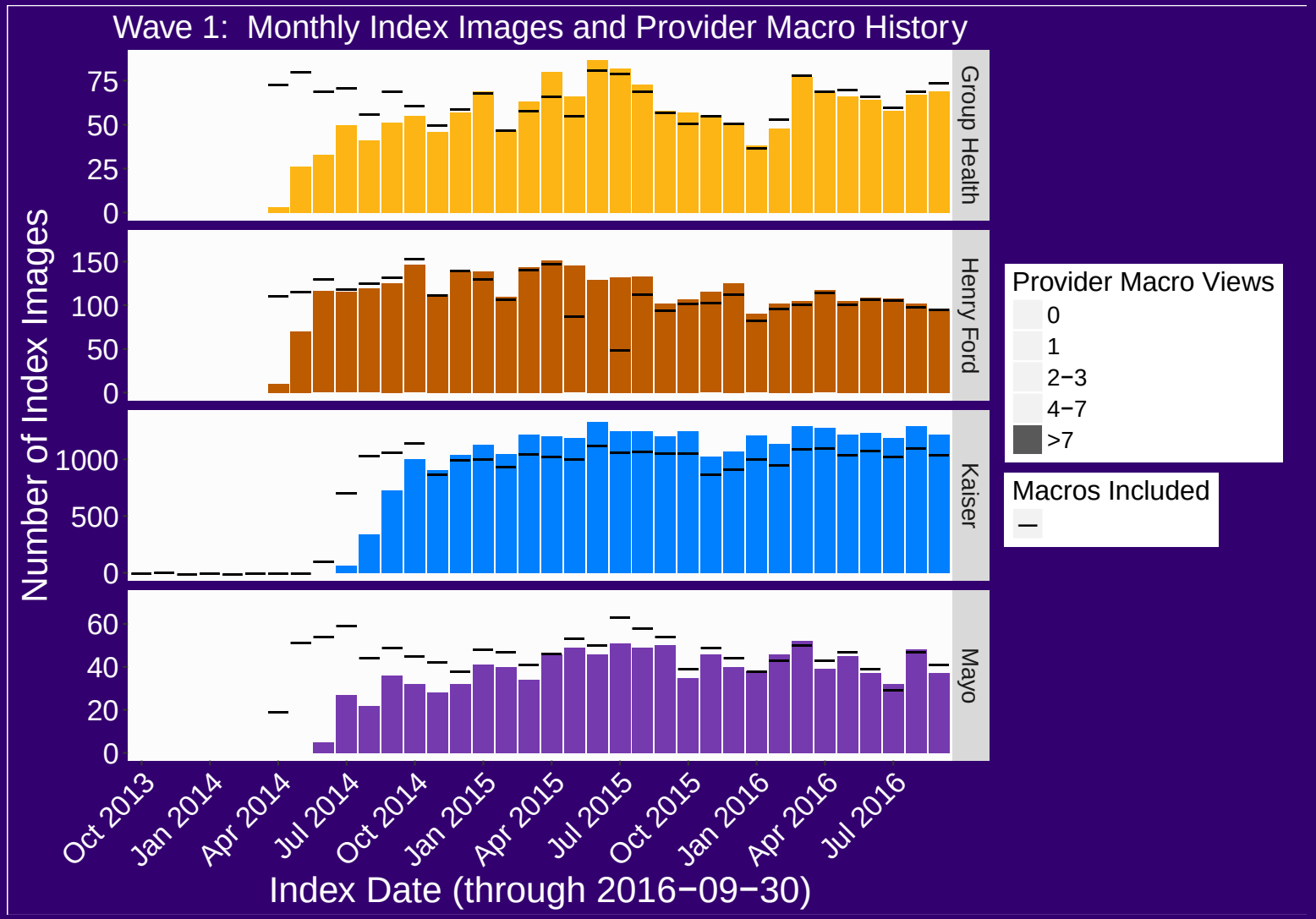
Hispanic Ethnicity



Imaging Modality

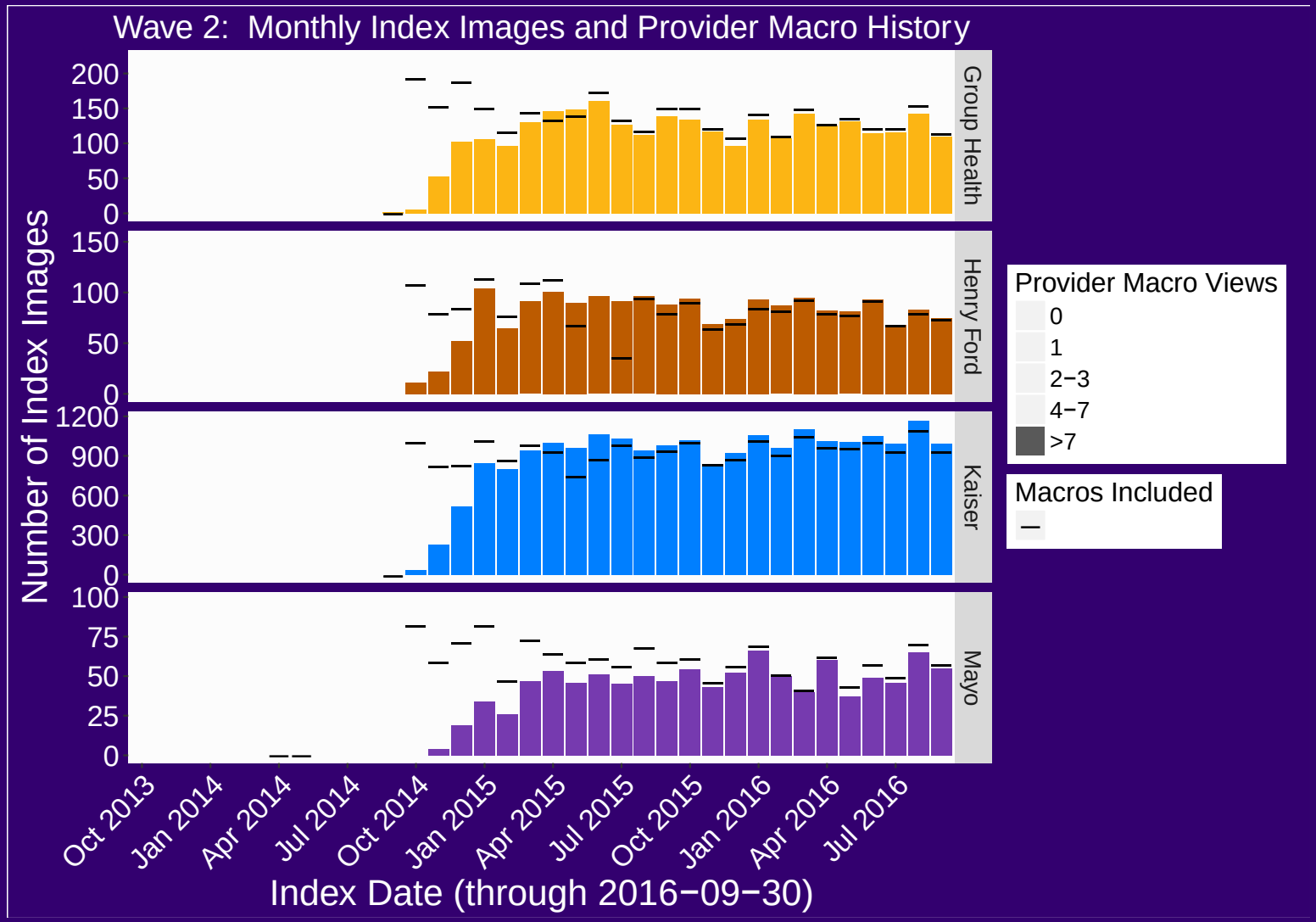


Macro Penetration at Wave 1 Clinics



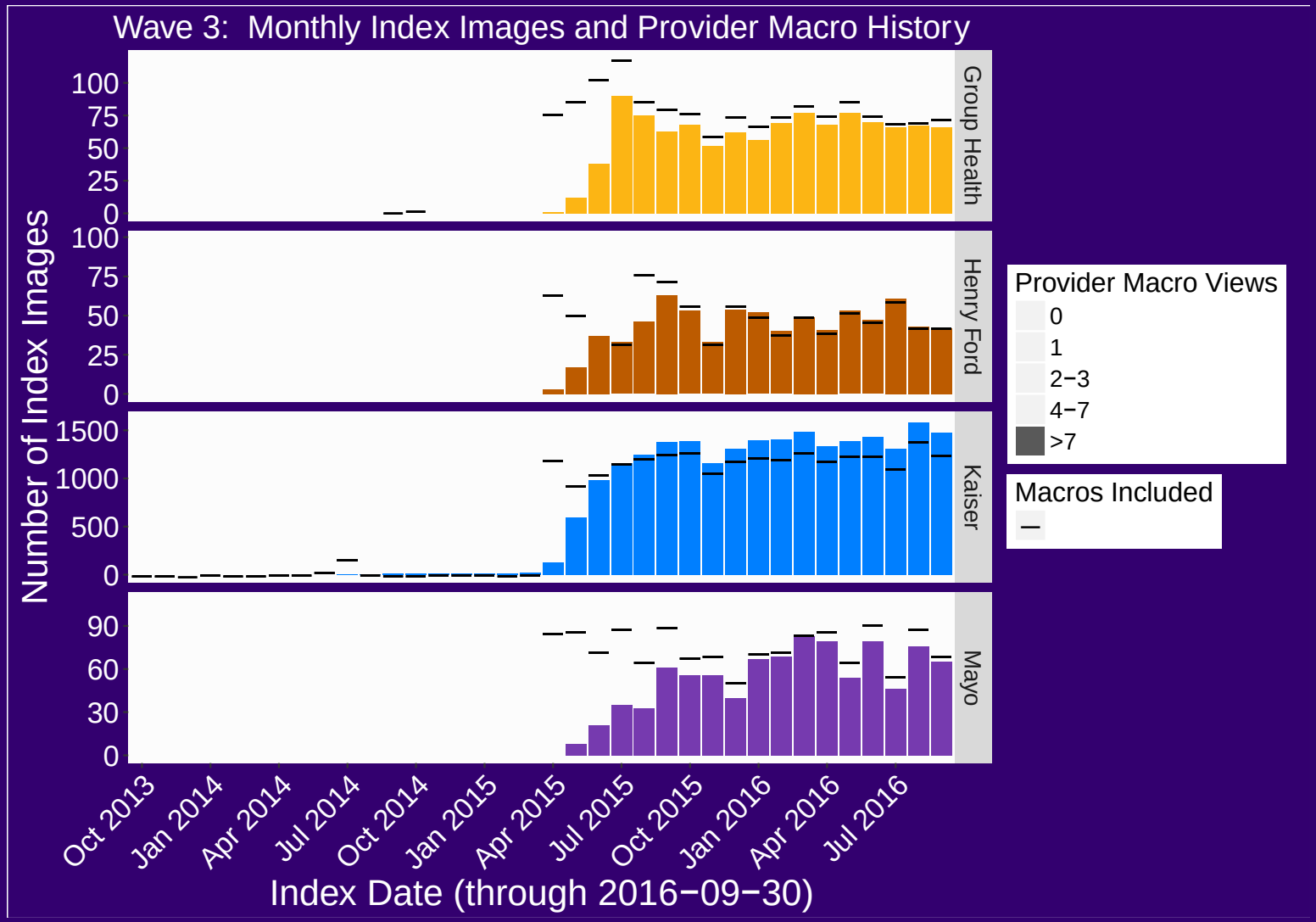
Shading indicates the number of macros that the patients' providers have been exposed to

Macro Penetration at Wave 2 Clinics



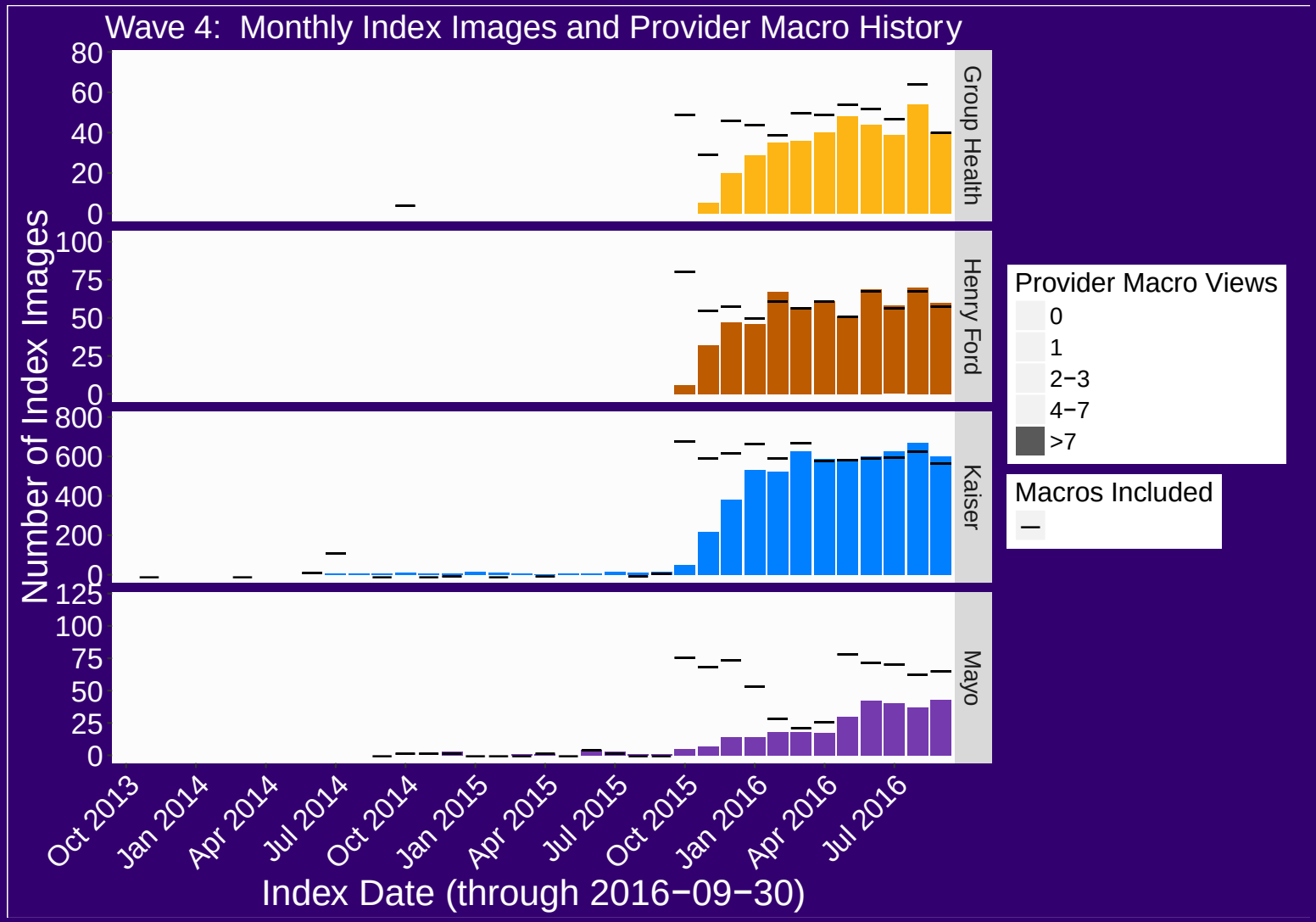
Shading indicates the number of macros that the patients' providers have been exposed to

Macro Penetration at Wave 3 Clinics



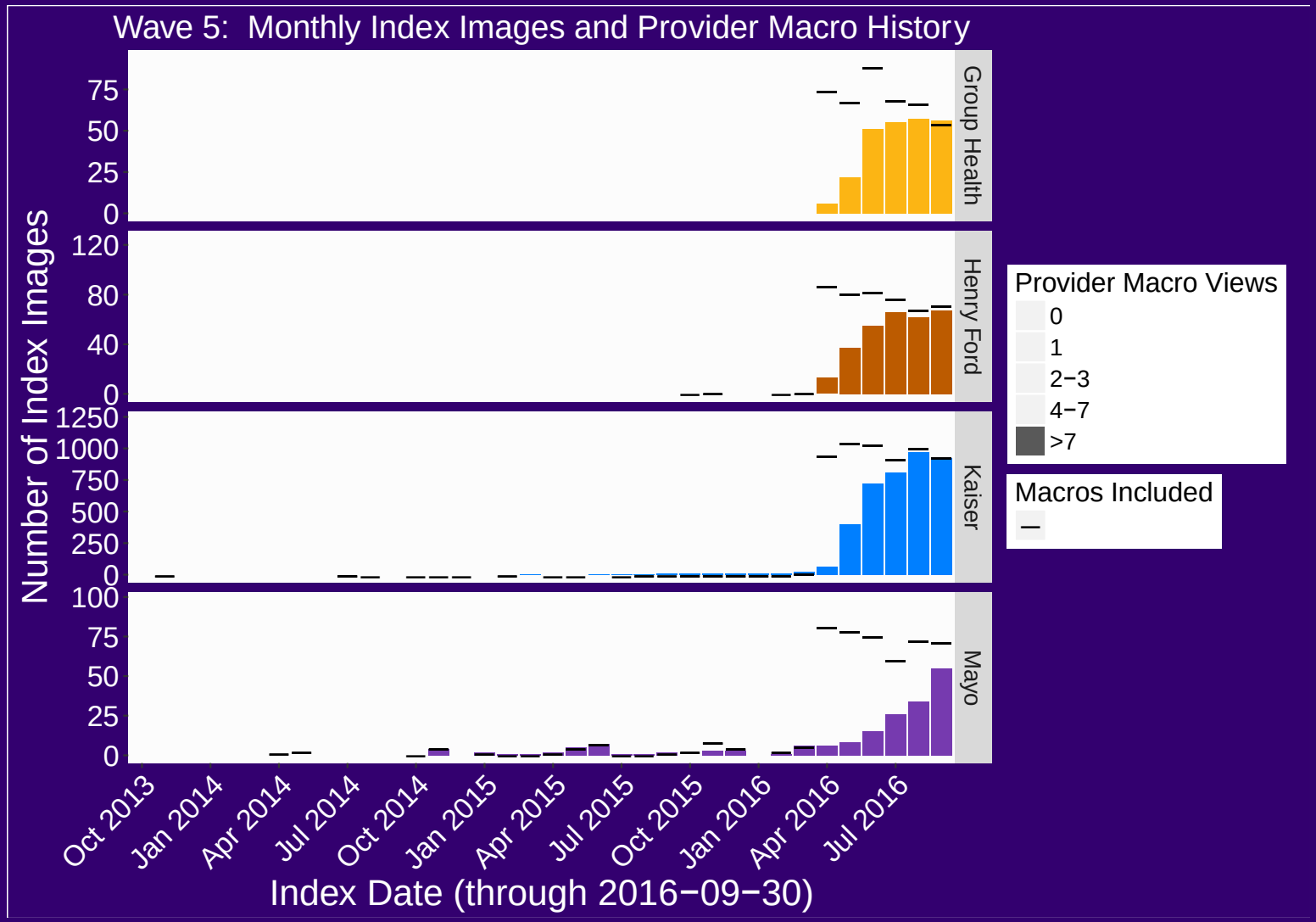
Shading indicates the number of macros that the patients' providers have been exposed to

Macro Penetration at Wave 4 Clinics



Shading indicates the number of macros that the patients' providers have been exposed to

Macro Penetration at Wave 5 Clinics



Shading indicates the number of macros that the patients' providers have been exposed to

"Now! … *That* should clear up a few things around here!"

Lessons Learned

Lessons Learned

- Provider Issues
- Health System Issues
- EMR Issues

Lessons Learned

- Provider Issues

- Health System Issues

- EMR Issues

*People (*Provider Issues): Lessons Learned

- Leadership is the start, not the end
- Engagement of as broad a group of providers as possible is key; for LIRE→ PCPs and radiologists
- Key individuals are key: mini-revolt for several weeks by rads at one clinic who didn't want to include text

Places (System Issues): Lessons Learned

"Change is the only constant in life" *Heraclitus*

- HFHS & Mayo: clinics defined by PCP, so needed constant updating of PCP list
- KPNC couldn't identify PCPs at first, but persistence pays
- You get what you pay for (Mayo-not initially paying programmers → less control over priority setting)

Things (EMR Issues): Lessons Learned

- Merging/harmonizing datasets from different sites challenging
- You've seen one, you've seen one (GHC-Epic implementation different/dynamic)
- Pragmatic = complex

Lessons Learned (So Far)

- Keep intervention as simple as possible
- Minimize burden on health system partners
- Primary outcome passively collected
- Budget for change

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NLP: The Problem

INDICATION: Left leg pain TECHNIQUE: Routine MRI Lumbar Spine Without Contrast FINDINGS: No fracture or subluxation. Conus is normal position without atrophy or edema. Benign hemangioma in L1 vertebral body. … Moderate facet hypertrophy. No stenoses. The disc has central annular fissure and mild generalized bulge. Mild left lateral recess narrowing. There is a large left central disc protrusion with annular fissure. This disc protrusion compresses and posteriorly displaces the traversing … radiculopathy. Mild central canal stenosis. IMPRESSION: 1. Moderate degenerative lumbar spondylosis. 2. … central disc protrusion compresses the left S1 nerve root. Suggest clinical correlation with left … vertebral body lesion is likely benign in the absence of known metastasizing malignancy.

"Gold" standard (ground truth).

Radiologist manually read and label sample $S \in \{0,1\}$ to obtain reference standard $D \in \{0,1\}$: *expensive* and *time consuming*.

NLP: The Goal

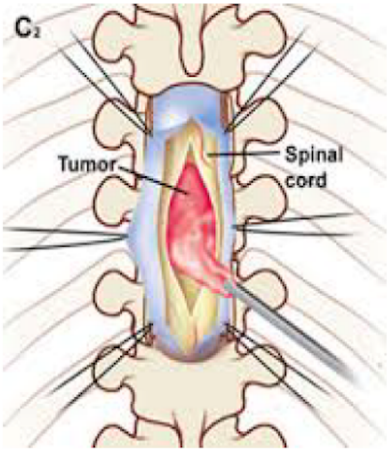
INDICATION: Left leg pain TECHNIQUE: Routine MRI Lumbar Spine Without Contrast FINDINGS: No fracture or subluxation. Conus is normal position without atrophy or edema. Benign hemangioma in L1 vertebral body. … Moderate facet hypertrophy. No stenoses. The disc has central annular fissure and mild generalized bulge. Mild left lateral recess narrowing. There is a large left central disc protrusion with annular fissure. This disc protrusion compresses and posteriorly displaces the traversing … radiculopathy. Mild central canal stenosis. IMPRESSION: 1. Moderate degenerative lumbar spondylosis. 2. … central disc protrusion compresses the left S1 nerve root. Suggest clinical correlation with left … vertebral body lesion is likely benign in the absence of known metastasizing malignancy.

→

	Var_1 …	Var_p	
$Report_1$	$X_{1,1}$	…	$X_{1,p}$
$Report_2$	$X_{2,1}$	…	$X_{2,p}$
⋮	⋮	⋮	⋮
$Report_N$	$X_{N,1}$	…	$X_{N,p}$

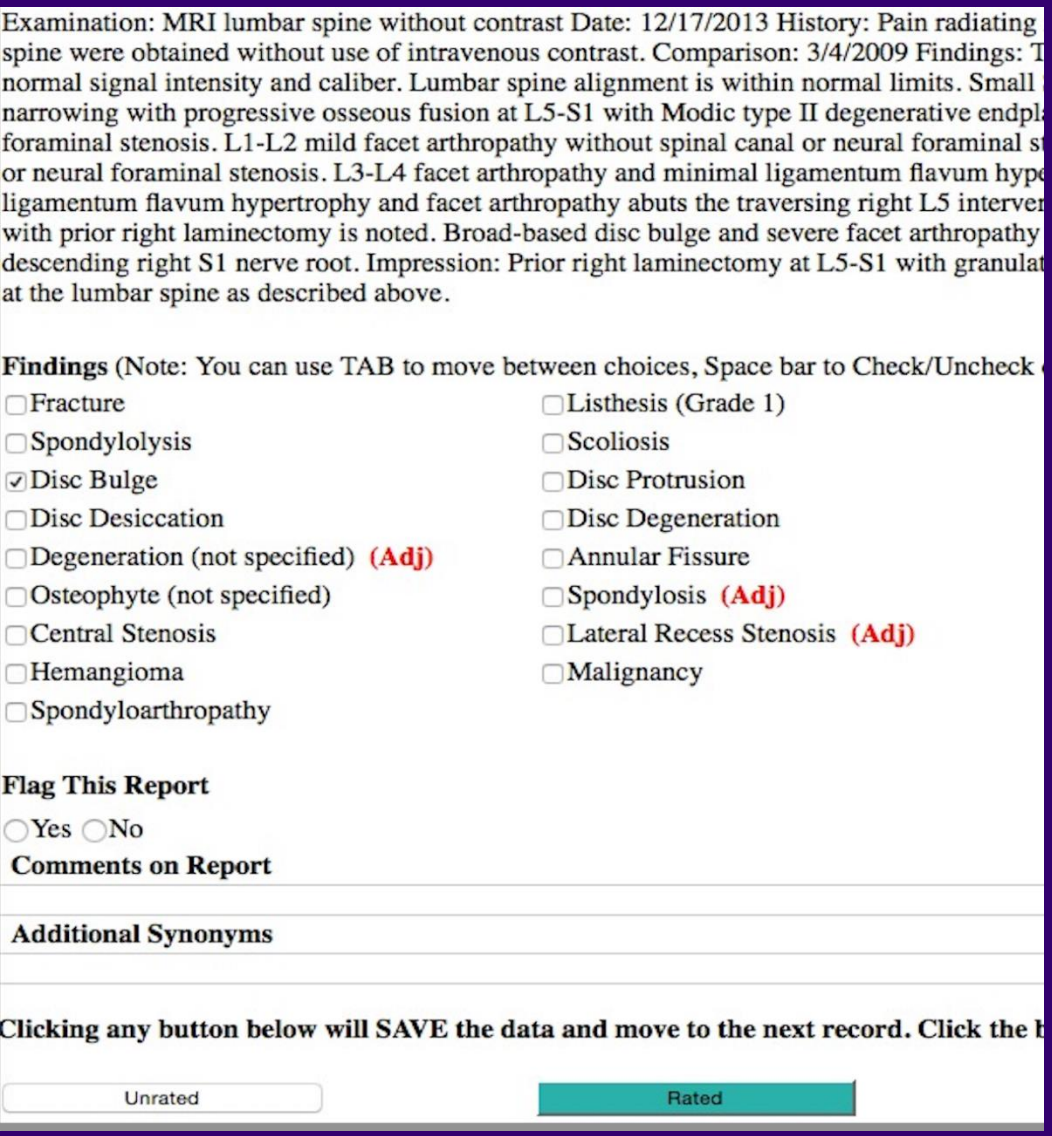
Create text-derived features **X**

→



Predictions of a rare disease e.g. spine cancer with a supervised classifier $h(\mathbf{X}) \rightarrow D$, e.g. regularized Logistic Regression.

NLP: Report Annotation



Examination: MRI lumbar spine without contrast Date: 12/17/2013 History: Pain radiating
spine were obtained without use of intravenous contrast. Comparison: 3/4/2009 Findings: T
normal signal intensity and caliber. Lumbar spine alignment is within normal limits. Small
narrowing with progressive osseous fusion at L5-S1 with Modic type II degenerative endpl
foraminal stenosis. L1-L2 mild facet arthropathy without spinal canal or neural foraminal s
or neural foraminal stenosis. L3-L4 facet arthropathy and minimal ligamentum flavum hyp
ligamentum flavum hypertrophy and facet arthropathy abuts the traversing right L5 interver
with prior right laminectomy is noted. Broad-based disc bulge and severe facet arthropathy
descending right S1 nerve root. Impression: Prior right laminectomy at L5-S1 with granulat
at the lumbar spine as described above.

Findings (Note: You can use TAB to move between choices, Space bar to Check/Uncheck

- ☐ Fracture
- ☐ Spondylolysis
- ☑ Disc Bulge
- ☐ Disc Desiccation
- ☐ Degeneration (not specified) **(Adj)**
- ☐ Osteophyte (not specified)
- ☐ Central Stenosis
- ☐ Hemangioma
- ☐ Spondyloarthropathy
- ☐ Listhesis (Grade 1)
- ☐ Scoliosis
- ☐ Disc Protrusion
- ☐ Disc Degeneration
- ☐ Annular Fissure
- ☐ Spondylosis **(Adj)**
- ☐ Lateral Recess Stenosis **(Adj)**
- ☐ Malignancy

Flag This Report

○ Yes ○ No

Comments on Report

Additional Synonyms

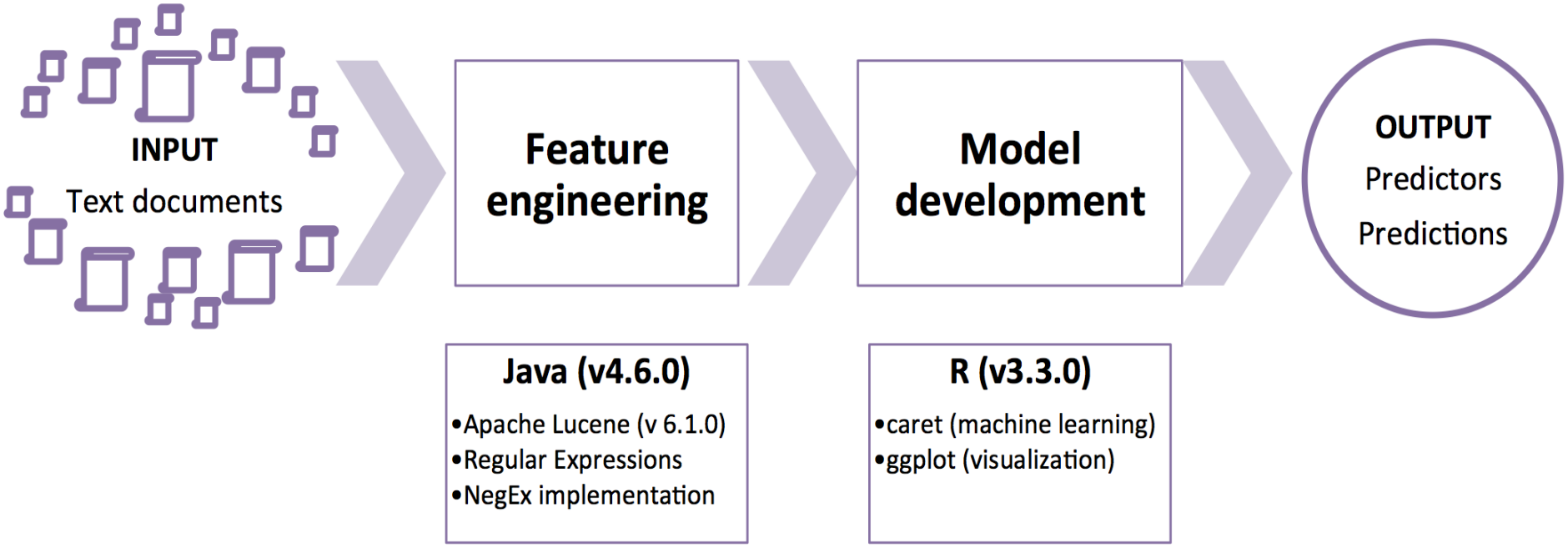
Clicking any button below will SAVE the data and move to the next record. Click the b

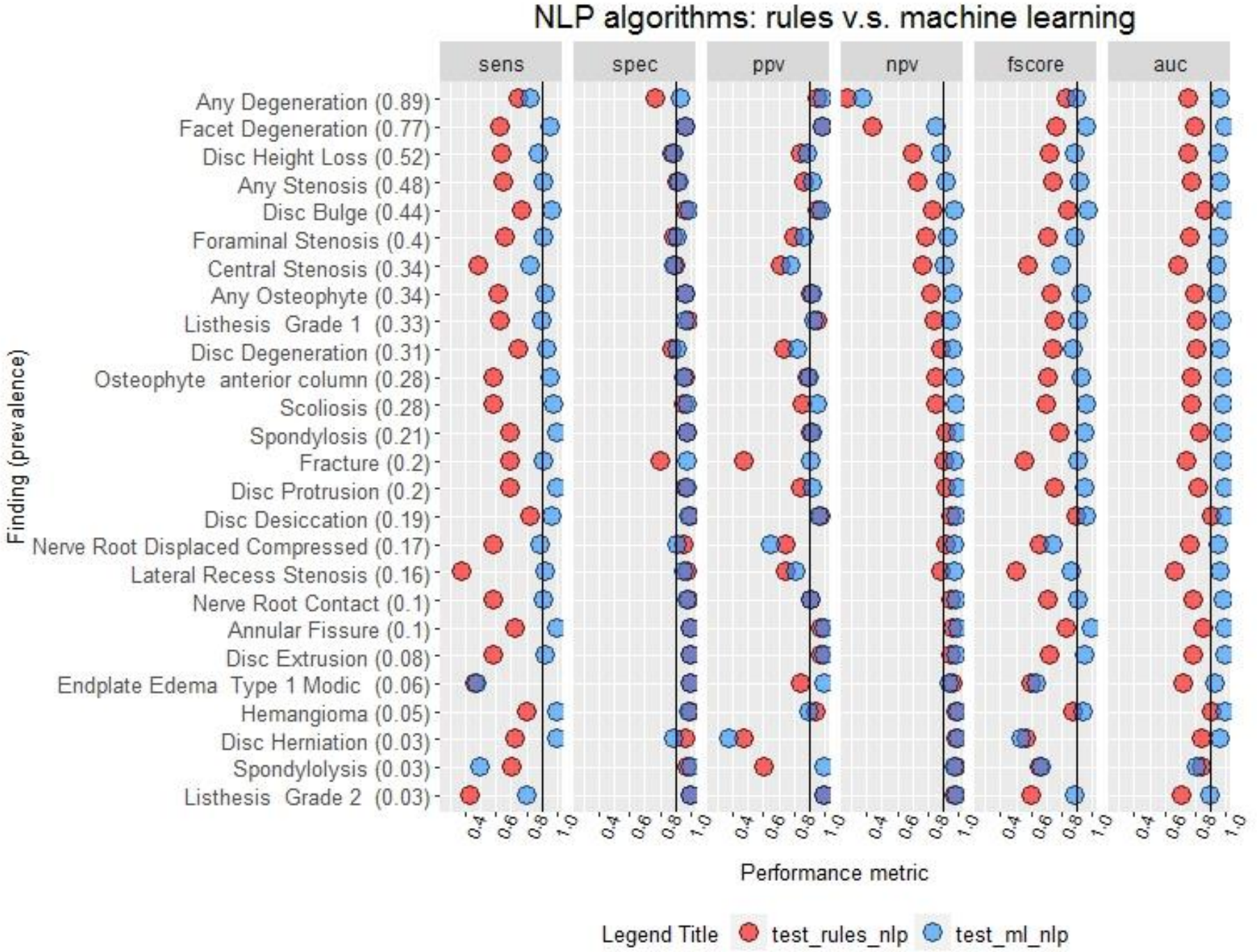
Unrated | Rated

- Multiple readers
- Data collection
- 871 reports
- QC process

NLP: Feature engineering

- *Rules-based synonyms*
- *Machine learning*
- *80/20 for development/test*




NLP algorithms: rules v.s. machine learning
sens
spec
ppv
npv
fscore
auc
Finding (prevalence)
Any Degeneration (0.89)
Facet Degeneration (0.77)
Disc Height Loss (0.52)
Any Stenosis (0.48)
Disc Bulge (0.44)
Foraminal Stenosis (0.4)
Central Stenosis (0.34)
Any Osteophyte (0.34)
Listhesis Grade 1 (0.33)
Disc Degeneration (0.31)
Osteophyte anterior column (0.28)
Scoliosis (0.28)
Spondylosis (0.21)
Fracture (0.2)
Disc Protrusion (0.2)
Disc Desiccation (0.19)
Nerve Root Displaced Compressed (0.17)
Lateral Recess Stenosis (0.16)
Nerve Root Contact (0.1)
Annular Fissure (0.1)
Disc Extrusion (0.08)
Endplate Edema Type 1 Modic (0.06)
Hemangioma (0.05)
Disc Herniation (0.03)
Spondylolysis (0.03)
Listhesis Grade 2 (0.03)
0.4
0.6
0.8
1.0
Performance metric
Legend Title
test_rules_nlp
test_ml_nlp

NLP: Summary

- *Katherine Tan (UW Biostatistics)*
- *Pre-processing / engineering*
- *Rules-based (REGEX)*
- *Machine learning included REGEX*
- *Rare findings need larger sample*
  - *N = 83 * 5 / prev*

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Next Steps

- 2017 Jan/Feb: Safety Officer Review
- 2017 1st qtr: NLP for radiology reports paper
- 2017 June: Opioids and RVU methods papers
- 2017 Oct-Nov: Data pull for primary outcome (12-month spine-related RVU)
- 2018 1st qtr:
  - Primary outcome paper
  - Opioid Rx paper
  - Cross-sectional imaging use paper
- 2018 3rd qtr: 24 month RVU and costs

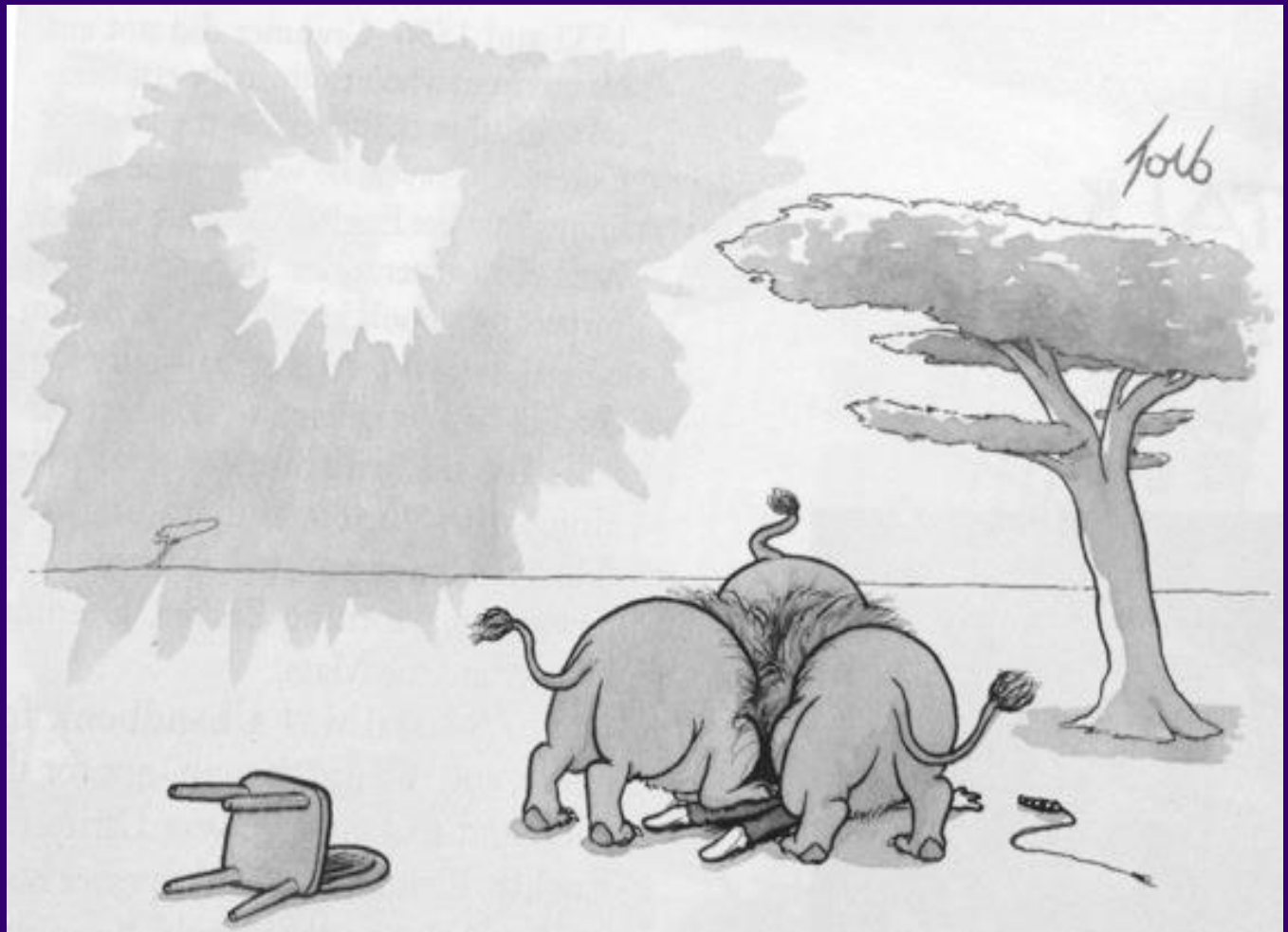
Other Papers

- Data quality methods (UW)
- Race/ethnicity/SES from EMR (UW)
- NLP for rare and serious findings (UW)
- Long-term opioids (UW)
- Percutaneous spine interventions (UW)
- Spine surgery (UW)
- Physical therapy (UW)
- Insurance influence on utilization (HF)
- Disc degeneration and diabetes (Mayo)
- Disparities and imaging modalities (Mayo)
- Imaging ordering patterns and indication (UW)

Key People

- Katie James, PA-C, MPH- PD
- Brian Bresnahan, PhD- Hlth Econ
- Bryan Comstock, MS- Biostats
- Janna Friedly, MD- Rehab
- Laurie Gold, PhD- Radiology
- Patrick Heagerty, PhD- Biostats
- Larry Kessler, PhD- HSR
- Danielle Lavallee, Pharm D, PhD
- Eric Meier, MS- Biostats
- Nancy Organ, MS- Biostats
- Kari Stephens, PhD- Informatics
- Judy Turner, PhD- Psychol/Psych
- Rick Deyo, MD, MPH- OHSU
- Dan Cherkin, PhD- GHRI
- Karen Sherman, PhD- GHRI
- Heidi Berthoud- GHRI
- Brent Griffiths, MD- HFHS
- Dave Nerenz, PhD- HFHS
- Dave Kallmes, MD- Mayo
- Patrick Luetmer, MD- Mayo
- Andy Avins, MD, MPH- KPNC
- Luisa Hamilton- KPNC

Why Pragmatic Trials Are Important



Barriers Scorecard

Barrier	Level of Difficulty				
	1	2	3	4	5
Enrollment and engagement of patients/subjects	X				
Engagement of clinicians and Health Systems		X			
Data collection and merging datasets		X			
Regulatory issues (IRBs and consent)	X				
Stability of control intervention		X			

1 = little difficulty; 5 = extreme difficulty