Exposure Indicator Tracking

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Disclosures

- None

Acknowledgments

- Kathleen Scilla (Cleveland State University)
- Ryan Fisher (Metro Health)

Outline

- Review the Exposure Index (EI) and Deviation Index (DI) as defined by IEC 62494-4
- Review key findings and takeaways from TG-232 regarding of the DI for ongoing quality control
- Discuss how to analyze EI data to assess the efficacy of dose-reduction measures taken during the DR retrofit process
- Discuss our experience using one methodology for setting target EI values (EI_T)

The Exposure Index (EI)

IEC standard 62494-1

Summary *IEC 62494-1*

- The IEC Exposure index (EI) is linear with incident detector air kerma
- The standard explicitly defines the conditions under which the EI shall be calibrated
    - Relationship between EI and incident detector air kerma will vary with beam quality

Exposure Index (EI)

- The exposure index (EI) shall be related to the value of interest (V) according to the formula:

$$\boldsymbol{EI = c_0 \cdot g(V)}$$

  - c_0 = 100 μGy^{-1}
  - $g(V)$ is the equipment-specific inverse calibration function

Inverse Calibration Function

- $g(V_{CAL})$ is the inverse calibration function:

$$\boldsymbol{K_{CAL} = f^{-1}(V_{CAL}) = g(V_{CAL})}$$

- The specified inverse calibration function shall have an uncertainty of less than 20% under calibration conditions

Exposure Index (EI)

- Thus, under calibration conditions:

$$EI = c_0 \cdot K_{CAL}$$

  - K_{CAL} is the receptor air kerma (in µGy) under calibration conditions (RQA5)
  - c_0 = 100 µGy^{-1}

Summary *IEC 62494-1*

- The standard does not define the method by which the vendor:
  - Determines the *Relevant Image Region*
  - Calculates the *Value of Interest*
- Calculated EI value for clinical images will be dependent on:
  - Beam quality
  - Patient anatomy
  - Vendor algorithms (for determination of VOI)

Deviation Index (DI)

- If target exposure index (EI_T) values are provided by the system, the deviation index (DI) shall be automatically calculated according to:

$$DI = 10 \cdot \log_{10}\left(\frac{EI}{EI_T}\right)$$

NOTE 1 For this purpose, the TARGET EXPOSURE INDEX values for different examinations/applications need to be available on the digital x-ray imaging system, e.g. in a data base. Such values may be established by professional societies or by the responsible organization.
IEC 62494-1 (page 12)

Exposure Indicator Tracking

Lessons from TG-232

TG-232

- Charge:
  - To investigate the current state of practice for CR/DR Exposure and Deviation Indices based on AAPM TG 116 and IEC-62949, for the purpose of establishing achievable goals (reference levels) and action levels in digital radiography

TG-232

- Findings:
  - Many DI fell outside TG-116 significant action limits
  - Mean DI was often not equal to 0.0
  - Use of AEC resulted in a narrower DI distribution

Jones K and Dave J., Diagnostic SAM session “Use of the deviation index (DI) for quality control in digital radiography”, AAPM Annual Meeting, Denver, CO July 31, 2017

TABLE XV. Recommended action limits and associated actions for the deviation index (DI).

DI	Possible action
DI outside ±1 standard deviation	Log for possible review, tally number of occurrences for periodic review
DI greater than +2 standard deviations	See fault tree in Fig. 7
DI less than −2 standard deviations	See fault tree in Fig. 8

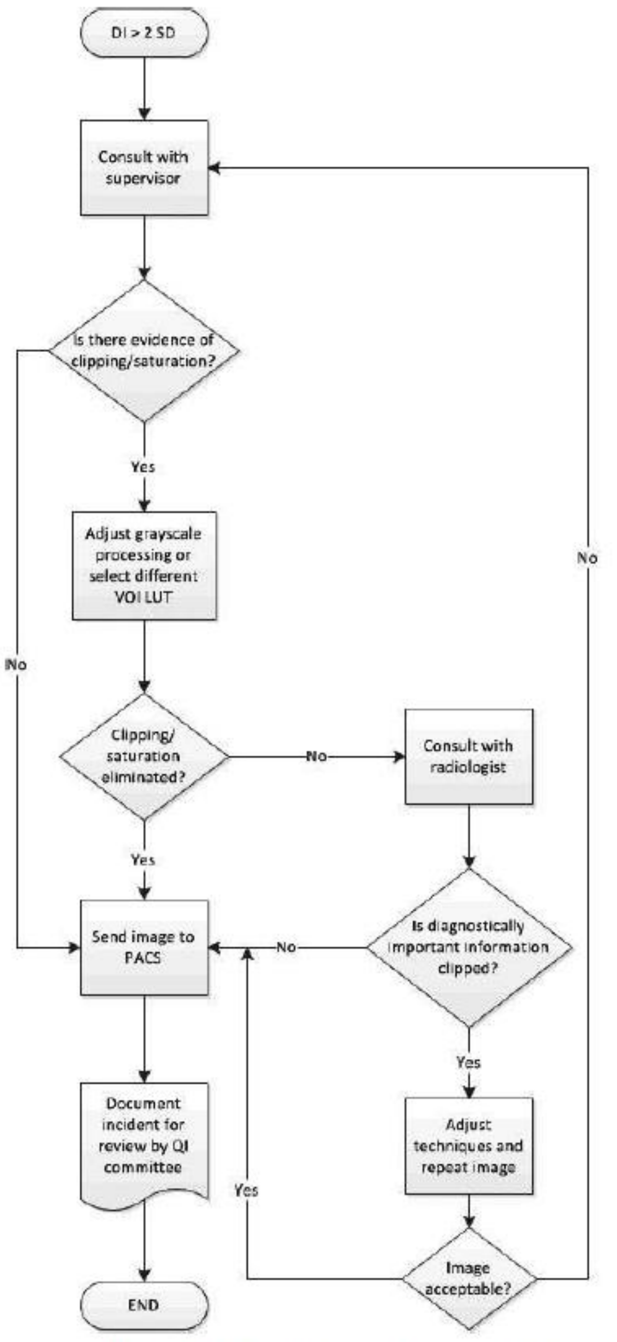

FIG. 7. Fault tree for DI greater than +2 standard deviations (SD).

Dave J., Jones A., Fisher R., Hulme K., et. al, Current state of practice regarding digital radiography exposure indicators and deviation indices: Report of AAPM Imaging Physics Committee Task Group 232, Med Phys 45(11): e1146-31160, 2018.

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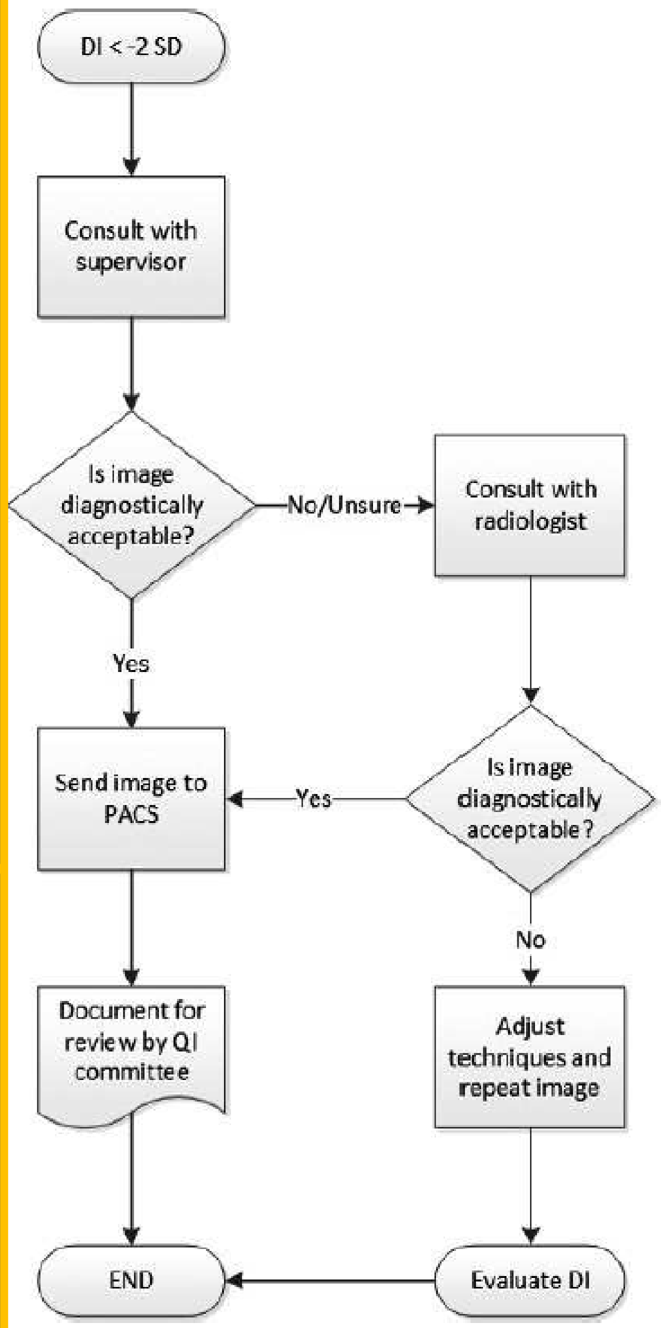


FIG. 8. Fault tree for DI less than −2 standard deviations (SD).

Dave J., Jones A., Fisher R., Hulme K., et. al, Current state of practice regarding digital radiography exposure indicators and deviation indices: Report of AAPM Imaging Physics Committee Task Group 232, Med Phys 45(11): e1146-31160, 2018.

Table XIII. Standard deviation (SD) of the DI for adult radiography.

Body part	View	Site with the smallest SD of the DI[a]		Site with the largest SD of the DI[a]	
		Number of exams	SD of DI	Number of exams	SD of DI
Abdomen	KUB	3746	1.8	8389	3.1
	Upright	931	1.3	1002	2.9
	Decubitus	6401	2.3	1200	3.6
Chest	AP	12491	2.0	43915	2.3
	PA	12061	1.7	20424	2.2
	Lateral	20810	1.7	16260	1.9
	Decubitus	–	–	–	–
Pelvis	AP	2236	1.6	1480	2.8
Extremity	Lower Extremity	17175	2.7	83209	3.3
	Upper Extremity	4877	1.8	21389	2.7

–: Insufficient sample size (data provided in Appendix A in Data S1 (Supporting Information) for reference).

[a]Number of examinations from site was at least 10% of the total number of examinations from all sites.

Typical distribution in DI was characterized by a SD of 1.3-3.6 and is affected by:

- Practice:
  - Techniques, AEC calibration
- Exposure indicator accuracy
- How the *value of interest* is calculated (vendor-specific)

Dave J., Jones A., Fisher R., Hulme K., et. al, Current state of practice regarding digital radiography exposure indicators and deviation indices: Report of AAPM Imaging Physics Committee Task Group 232, Med Phys 45(11): e1146-31160, 2018.

TG-232 Recommendations

Step 1

- “This task group recommends that a mean DI of 0.0 be targeted for all body parts and views. This requires that EI_T values be set appropriately”

Dave J., Jones A., Fisher R., Hulme K., et. al, Current state of practice regarding digital radiography exposure indicators and deviation indices: Report of AAPM Imaging Physics Committee Task Group 232, Med Phys 45(11): e1146-31160, 2018.

TG-232 Recommendations

Step 2

- “As a starting point, this task group recommends that action limits for the DI be set at ±1 and ±2 SD of the DI based on actual DI data of an individual site… ”

Dave J., Jones A., Fisher R., Hulme K., et. al, Current state of practice regarding digital radiography exposure indicators and deviation indices: Report of AAPM Imaging Physics Committee Task Group 232, Med Phys 45(11): e1146-31160, 2018.

Methodology

Analyzing EI/DI Dose Statistics

Objectives

- Ensure techniques (manual and photo-timed) were successfully reduced for the change in detector technology
- Determine the appropriate EI_T values (by body part and/or view) to achieve a mean DI of 0.0

Data Collection

- Scope of retrofits:
  - 38 Agfa DR 14s panels
  - 25 different sites
- Subset of units selected
- Data exported from:
  - ★ 5 Sites
  - 8 workstations

Data Collection

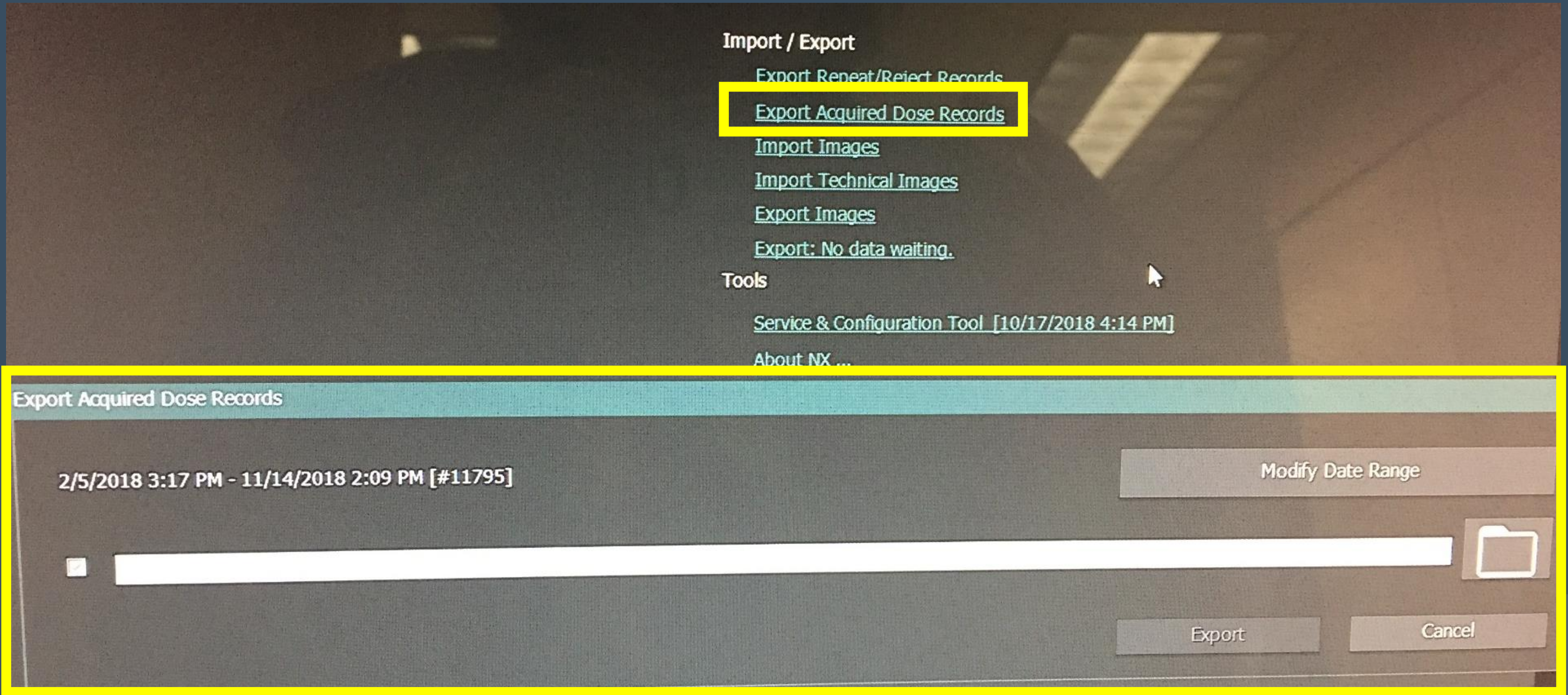
- Subset of units selected
- Data exported from:
  - 5 Sites
  - 8 workstations

Make	Model	Count
Shimadzu	**RadSpeed**	**20**
Reliance	ATC 725	5
Shimadzu	Fluoro Speed	3
Quantum	MC 150 Pinnacle	2
Siemens	Multix Top Pro	2
Bennett	Compu-mAs	1
GE	AMX-4	1
Philips	Easy Diagnost Eleva	1
Philips	Optimus	1
Picker	RadView 65	1
Siemens	Sireskop SD	1

- Criteria for selected workstations:
  - Workstation was affiliated with a single radiographic unit and CR reader prior to DR retrofit
  - Workstation was affiliated with a Shimadzu RadSpeeds

- Comments:
  - 7 units used Agfa HD5.0 CR plates
  - 1 unit used Agfa MD4.0 CR plates

Exporting Dose Statistics



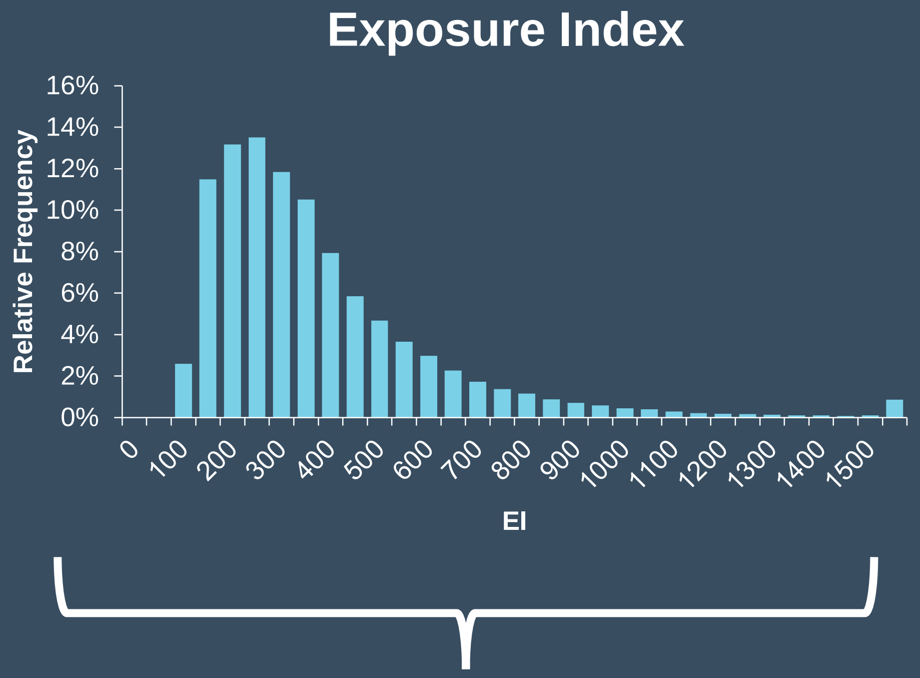
Data Collection

- Prior to DR retrofits, collected 12 months of EI data from 8 CR workstations
- Data extracted ~3 months following DR panel installation from the same 8 workstation (preliminary DR dataset)*
- Data extracted again 12 months following DR panel installation from the same 8 workstations (final DR dataset, includes preliminary data)

Detector Technology	Months of Dose Stats	*N* - Exams
CR	12	133,759
DR	~3 (preliminary*)	39,658
DR	12	141,209

* Preliminary data presented at 2018 AAPM annual meeting - **Hulme K.**, Scilla K., Fisher R.*, Li X., *Investigation of State-of-Practice Using Exposure Index (EI) Data Following Digital Radiography (DR) Retrofits of Eight Radiographic Units*, Med Phys 45(6):e694, 2018.

Methodology

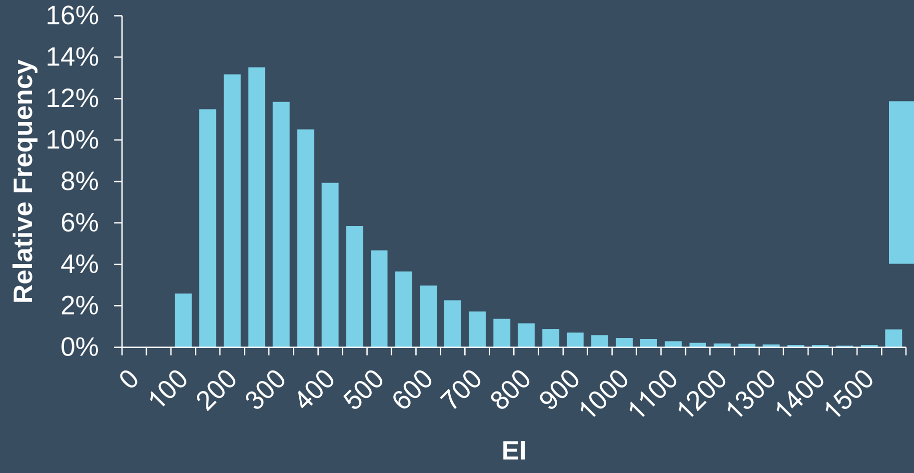


Distribution in exposure index is log-normal

- Collected and analyzed EI values for each exam group *(k)*

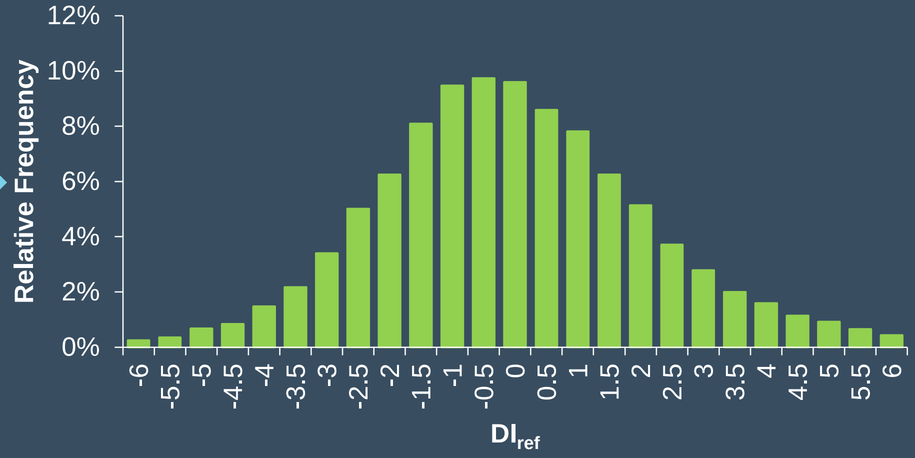
Methodology

Exposure Index



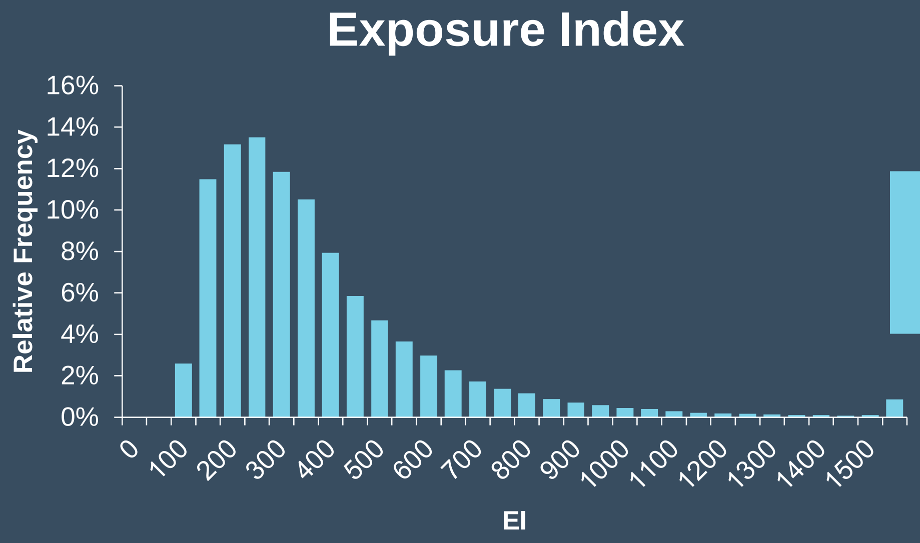
$$DI_{ref} = 10 * \log \frac{EI}{TEI_{ref}}$$

Deviation Index



Distribution in deviation index is normal (usually…)

Methodology



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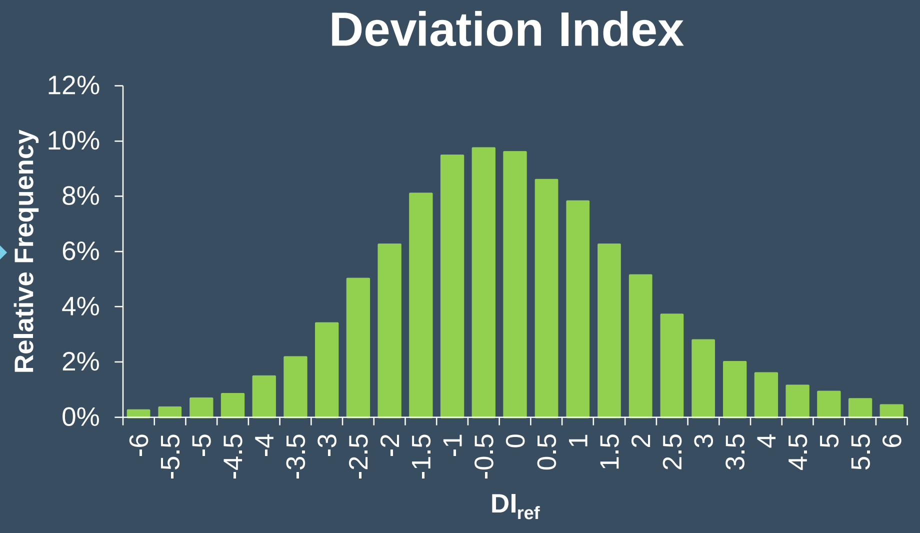
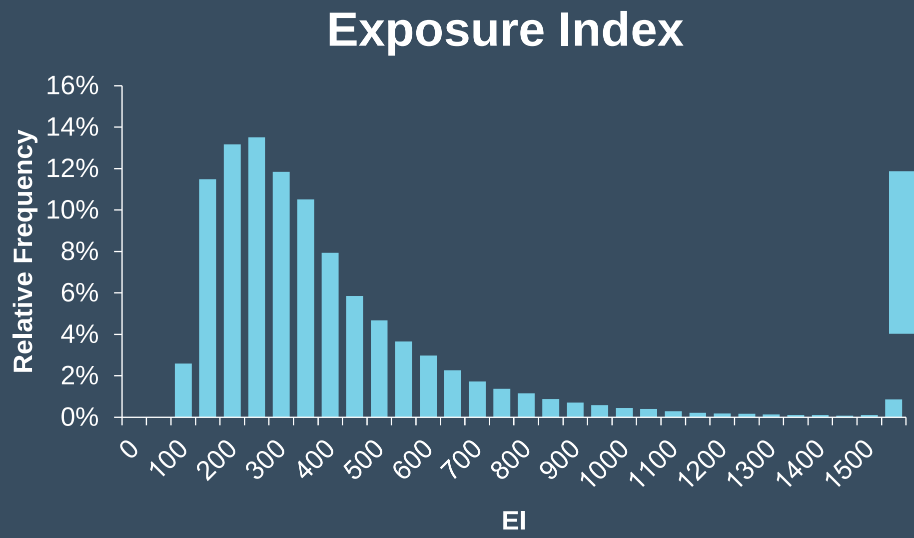
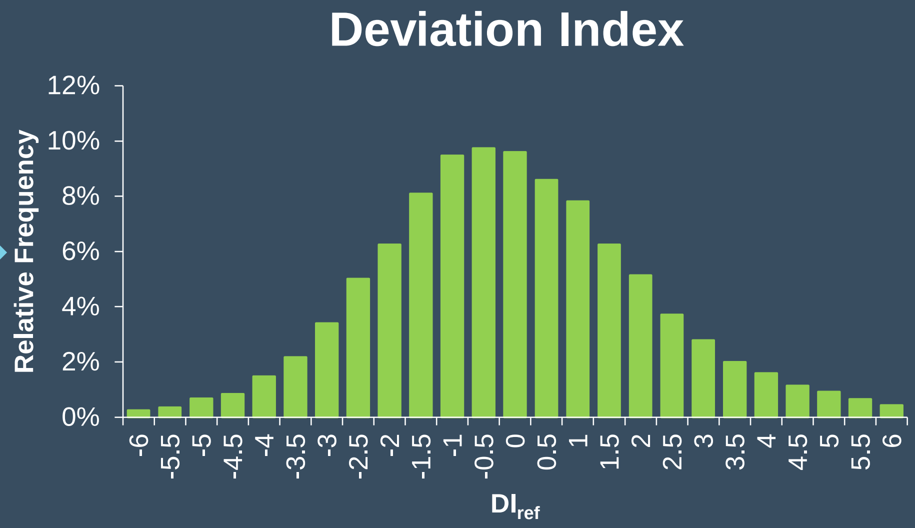


- Calculated DI_{ref} for each exposure index using a TEI_{ref} of 400 for CR exams and 250 for DR exams

Methodology

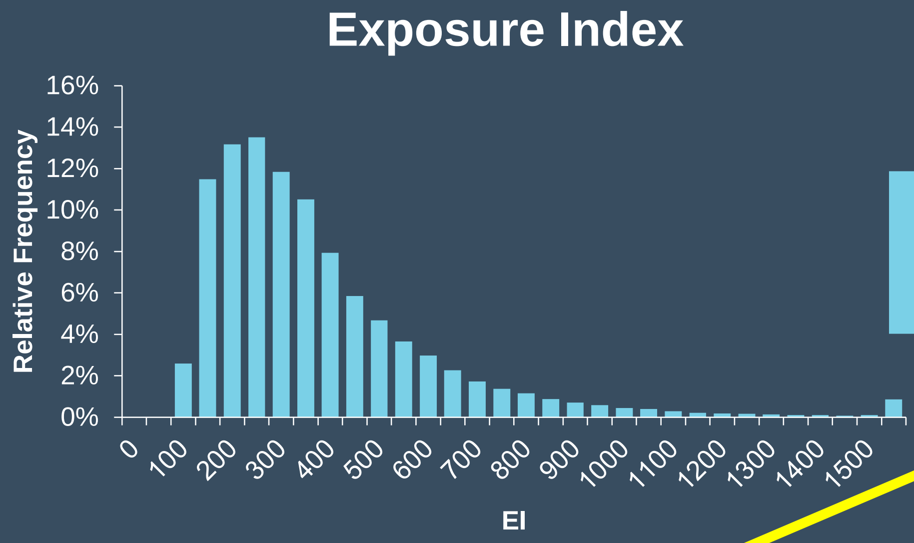


$$DI_{ref} = 10 * \log \frac{EI}{TEI_{ref}}$$

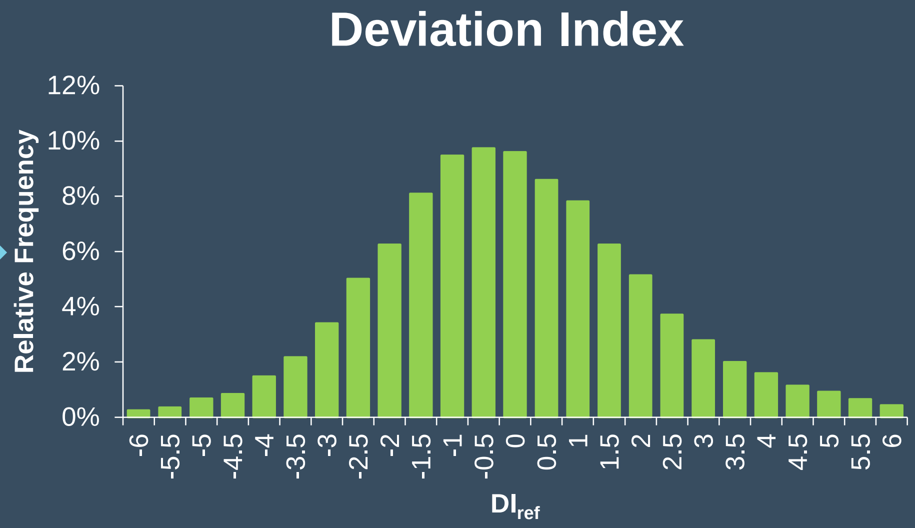


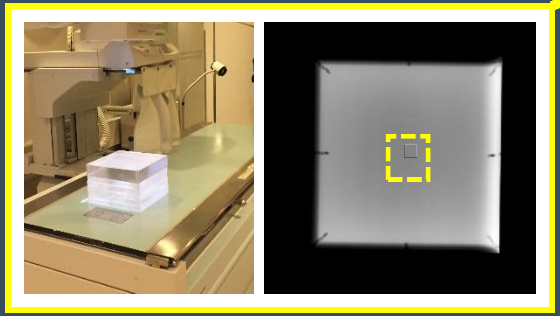
- Note: for a normal distribution, choice of TEI_{ref} will not affect the $SD(DI_{ref})$, only the mean

Methodology



$$DI_{ref} = 10 * \log_{10}\frac{EI}{TEI_{ref}}$$



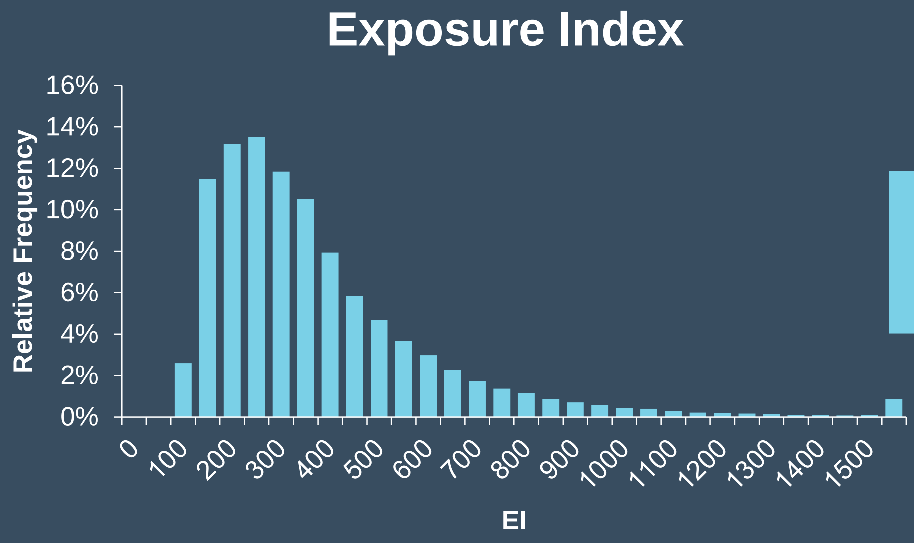


“Reference EI_T” (TEI_{ref}) ← *Not defined by IEC, metric used for analysis purposes only*

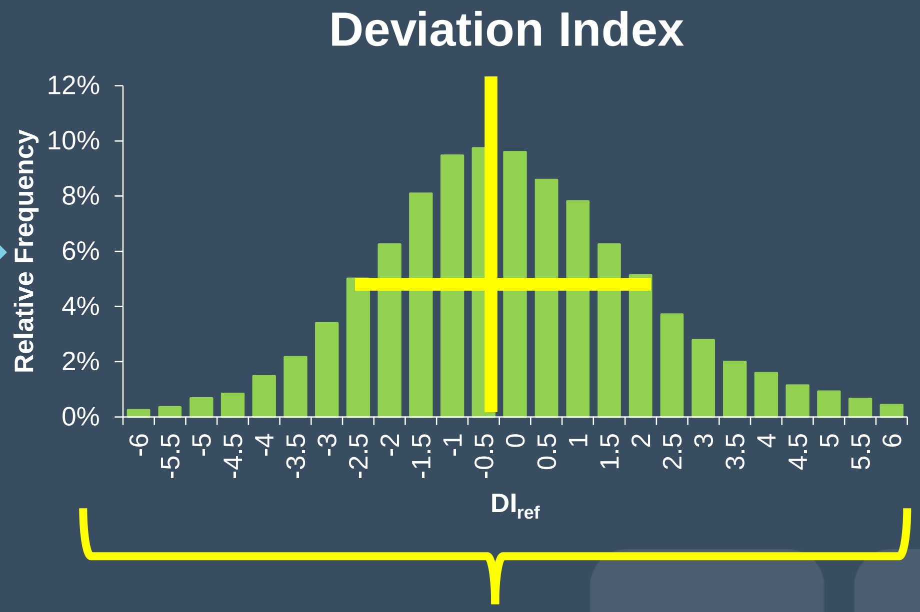
EI corresponding to target detector dose used for AEC calibration

- CR: TEI_{ref} = 400 (target detector dose 4.0 µGy for MD 4.0)
- DR: TEI_{ref} = 250 (target detector dose 2.5 µGy for Agfa DR 14s)

Methodology



$$DI_{ref} = 10 * \log \frac{EI}{TEI_{ref}}$$

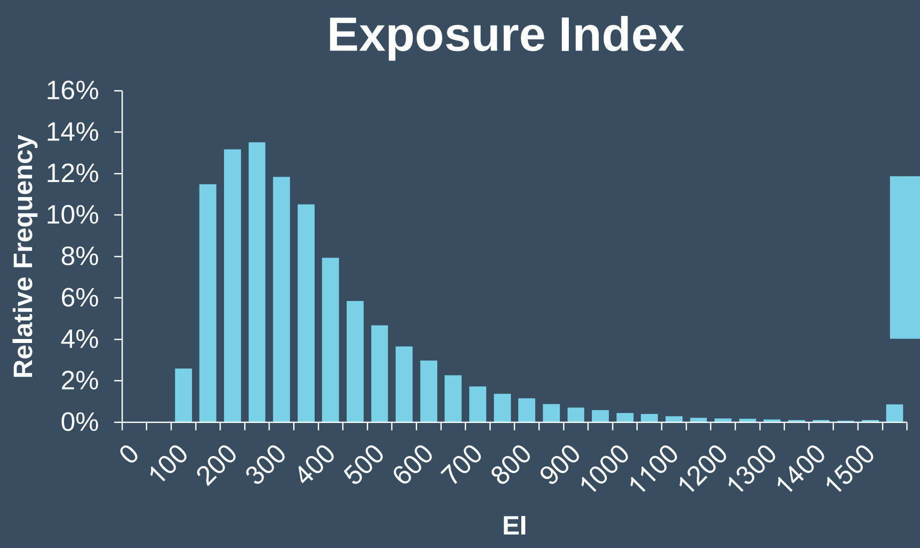


Mean ($DI_{ref,k}$)

SD($DI_{ref,k}$)

- Calculated mean and standard deviation in DI_{ref} for each exam group (*k*)
-

Methodology



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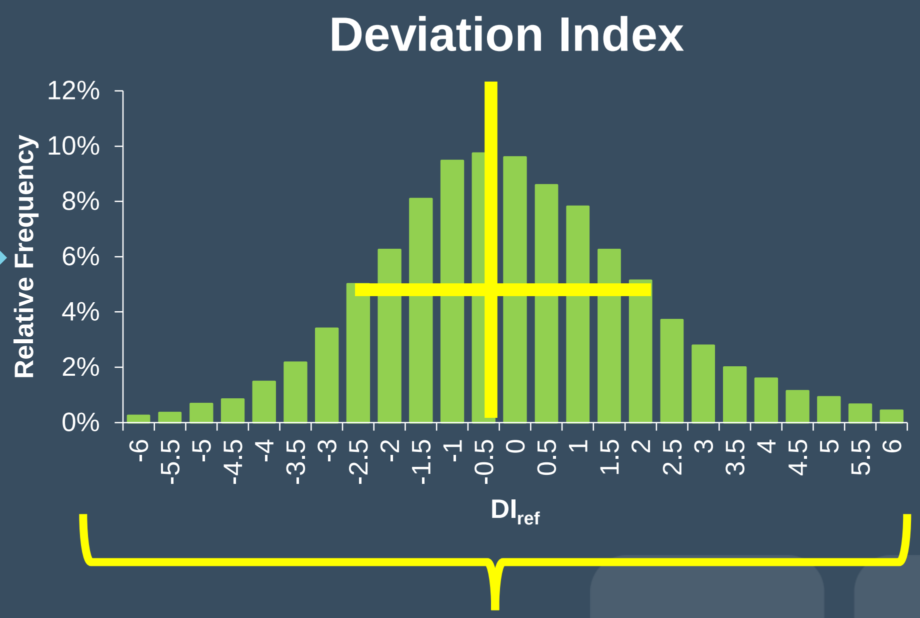


Mean ($DI_{ref,k}$)

SD($DI_{ref,k}$)

$$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{\text{Mean}(DI_{ref,k})}{10}}$$

$EI_{ref,k}$

EI value corresponding with mean DI_{ref} for a given exam exam group *(k)*

Assessing Dose-Reduction Measures

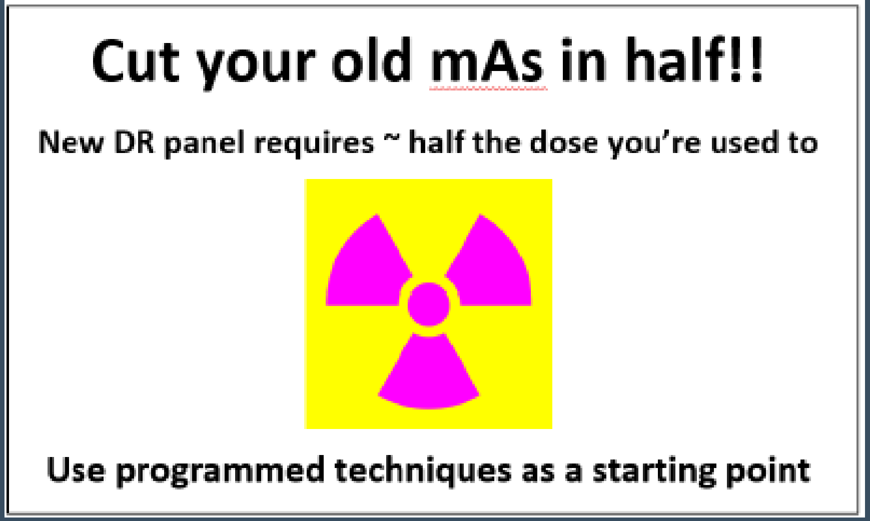
Post-Retrofit Performance

Objectives

- Ensure techniques (manual and photo-timed) were successfully reduced for the change in detector technology
- Determine the appropriate EI_T values (by body part and/or view) to achieve a mean DI of 0.0

Steps to Success:

TABLETOP					
				Manual Technique	
Exam Group	View	SID (in)	Grid	kVp	mAs
Ankle	AP	40	N	60	2.5
	OBL	40	N	60	2.5
	LAT	40	N	60	2.5
Elbow	AP	40	N	60	2.0
	OBL	40	N	60	2.0
	LAT	40	N	60	2.0
Finger	AP	40	N	55	1.2
Foot	AP	40	N	56	2.0
	LAT	40	N	58	2.0
Forearm	AP	40	N	58	2.0
Hand	AP / OBL	40	N	60	1.5
	LAT	40	N	63	1.5
Heel	LAT	40	N	60	2.5
	Axial	40	N	66	4.9
Hip	Hip	40	N	68	6.8
	cross-table	40	N	85	37.1
Humerus	Humerus	40	N	65	3.1
Knee	AP	40	N	65	2.0
	LAT	40	N	65	2.0
	Tunnel	40	N	70	2.5
	Merchant	40	N	70	2.5
Shoulder	Axilary	40	N	70	4.9
Tib/Fib	Leg	40	N	65	2.5



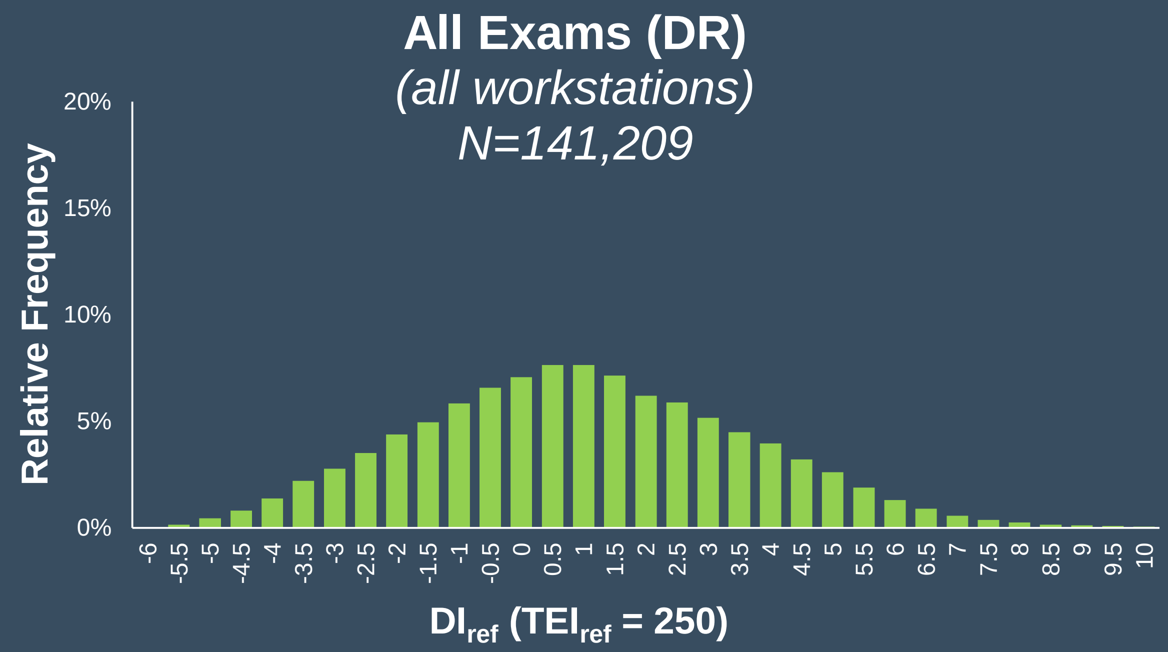
Calibrate AEC

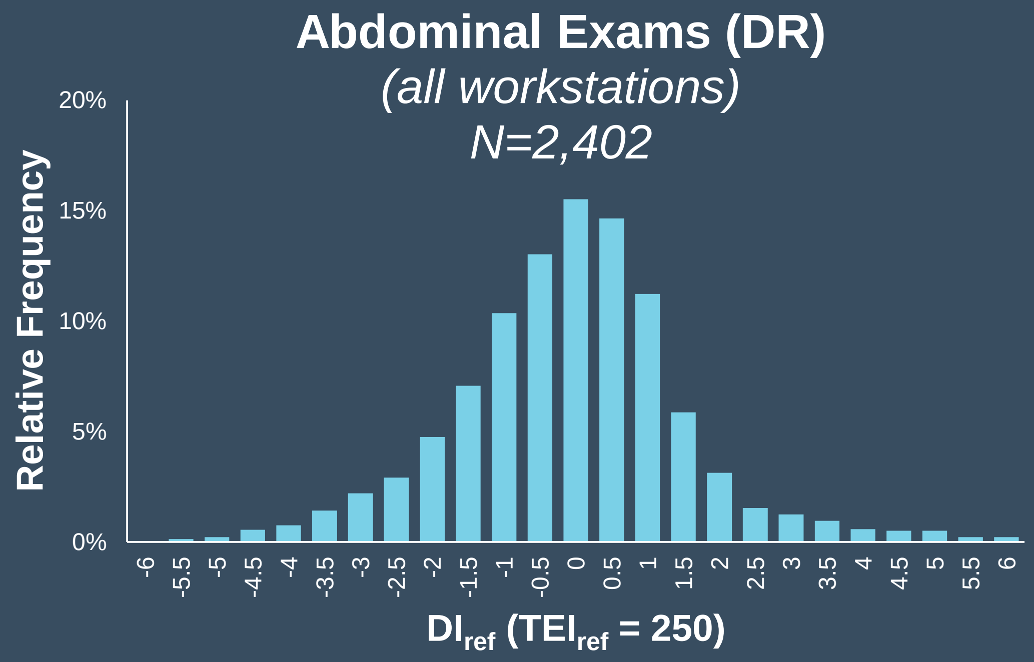
Develop Manual Technique Chart

Program the APR

Educate Technologists

Analysis by Exam Group





$EI_{ref,k}$

EI value corresponding with mean DI_{ref} for a given exam exam group *(k)*

→

Compare $EI_{ref,k}$ before and retrofit to determine nominal dose reduction for that exam group

RESULTS

Phototimed Exam Groups

- Saw reductions in mean $EI_{ref,k}$ for all exam groups (~40%)
- Expected dose reductions of ~ 28% for HD5.0 CR plates and ~ 37% for MD4.0 plates

Exam Group *(k)* - *Phototimed*	*N*		$EI_{ref,k}$		
	CR	DR	CR	DR	% Diff
Abdomen	2476	2401	318	247	-22%
Abdomen GI	205	152	403	320	-21%
Abdomen GU	483	501	338	250	-26%
C-Spine	5978	5357	372	235	-37%
Chest	25780	15777	296	155	-48%
Femur Knee Leg	29319	34963	457	300	-34%
L/S Spine	11102	9556	636	329	-48%
Mandible & TMJ	82	78	332	232	-30%
Nasal and Orbits	177	58	284	271	-5%
Pelvis & Hip	13489	14926	606	326	-46%
Shoulder	10407	11785	455	334	-36%
Skull, Sinus & Facial	489	478	425	334	-21%
T-Spine	1503	1411	534	273	-49%
Total:	**101490**	**97443**	**Weighted Average:**		**-40%**

Exam Group (k) - *Phototimed*	*N*		$EI_{ref,k}$		
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- Expected dose reductions of ~ 28% for HD5.0 CR plates and ~ 37% for MD4.0 plates
- Larger reduction in chest imaging also due to change in speed class setting
- Large reductions in L/S Spine & Pelvis & Hip groups due to erroneous EI values (>5000) in the CR data due to segmentation issues

RESULTS

Phototimed Exam Groups

- Standard deviation in $DI_{ref,k}$ was reduced, on average, by 0.4

Exam Group *(k)* - *Phototimed*	***N***		**$SD(DI)_{ref,k}$**		
	CR	DR	CR	DR	**Diff**
Abdomen	2476	2401	2.60	1.69	-0.90
Abdomen GI	205	152	1.68	2.14	0.46
Abdomen GU	483	501	2.55	1.86	-0.69
C-Spine	5978	5357	2.68	2.57	-0.11
Chest	25780	15777	2.52	1.63	-0.89
Femur Knee Leg	29319	34963	2.38	2.54	0.16
L/S Spine	11102	9556	3.17	1.70	-1.47
Mandible & TMJ	82	78	2.03	2.44	0.42
Nasal and Orbits	177	58	3.08	2.46	-0.62
Pelvis & Hip	13489	14926	2.82	2.31	-0.51
Shoulder	10407	11785	2.86	2.60	-0.26
Skull, Sinus & Facial	489	478	2.16	2.01	-0.15
T-Spine	1503	1411	2.94	2.58	-0.36
Total:	**101490**	**97443**	**Weighted Average:**		**-0.42**

Exam Group *(k)* - *Phototimed*	***N***		**SD(DI)$_{ref,k}$**		
	CR	DR	CR	DR	**Diff**
Abdomen	2476	2401	2.60	1.69	-0.90
Abdomen GI	205	152	1.68	2.14	0.46
Abdomen GU	483	501	2.55	1.86	-0.69
C-Spine	5978	5357	2.68	2.57	-0.11
Chest	25780	15777	2.52	1.63	-0.89
Femur Knee Leg	29319	34963	2.38	2.54	0.16
L/S Spine	11102	9556	3.17	1.70	-1.47
Mandible & TMJ	82	78	2.03	2.44	0.42
Nasal and Orbits	177	58	3.08	2.46	-0.62
Pelvis & Hip	13489	14926	2.82	2.31	-0.51
Shoulder	10407	11785	2.86	2.60	-0.26
Skull, Sinus & Facial	489	478	2.16	2.01	-0.15
T-Spine	1503	1411	2.94	2.58	-0.36
Total:	**101490**	**97443**	**Weighted Average:**		**-0.42**

RESULTS

Phototimed Exam Groups

- Standard deviation in $DI_{ref,k}$ was reduced, on average, by 0.4
- A reduction in $DI_{ref,k}$ was observed for all exam groups *except*:
  - Abdomen GI*
  - Femur Knee Leg
  - Mandible & TMJ*

**low volume*

RESULTS

Manual Exam Groups

- Saw reductions in mean $EI_{ref,k}$ for all exam groups

Exam Group *(k)* - *Manual*	***N***		**$EI_{ref,k}$**		**% Diff Full**
	CR	DR	CR	DR	
Ankle & Foot	16308	20941	785	406	-48%
Hand & Wrist	11608	17368	890	645	-28%
Humerus, Elbow, Forearm	4553	5457	930	574	-38%
Total:	**32269**	**43755**	**Weighted Average:**		**-39%**

RESULTS

Manual Exam Groups

Exam Group *(k)* - *Manual*	***N*** CR	DR	**SD($EI_{ref,k}$)** CR	DR	**Diff**
Ankle & Foot	16308	20941	2.01	2.15	0.14
Hand & Wrist	11608	17368	1.74	2.16	0.43
Humerus, Elbow, Forearm	4553	5457	2.28	2.06	-0.23
Total:	**32269**	**43755**	**Weighted Average:**		**0.20**

- Saw reductions in mean $EI_{ref,k}$ for all exam groups
- Standard Deviation in DI changes had mixed results
  - Ankle & foot groups were similar
  - Hand & wrist groups increased
  - Humerus, Elbow, & Forearm decreased
- Initial review of site data for Hand & Wrist exam group showed no explanation for increase in SD(DI)
  - Next step is a more granular analysis of individual views

Conclusions

- Exposure indices corresponding to mean(DI_{ref}) reduced for all exam groups
  - Average reduction of 40% for both phototimed and manual exams
- Standard deviation in DI decreased for most exam groups
- Dose reduction is possible when transitioning from CR to DR… but work must be done!

Setting Target EI (EI_T) Values

New Detector – New Targets!

Objectives

- Ensure techniques (manual and photo-timed) were successfully reduced for the change in detector technology
- Determine the appropriate EI_T values (by body part and/or view) to achieve a mean DI of 0.0

Preliminary EI_T

- Initial set of EI_T values provided to applications at install were derived from our EI_T values for CR
  - E_T values linearly scaled for change in target detector dose:

$$EI_{T,DR} = \frac{2.5\mu Gy}{4.0\mu Gy} EI_{T,CR}$$

  - EI_T values were assigned by exam group and were not broken down by view

Preliminary EI_T

- Initial set of EI_T values provided to applications at install were derived from our EI_T values for CR
- However:
  - Values were derived from data collected in 2013
  - Different detector technologies (different sensitivities to beam quality)
  - Several tweaks made to manual technique charts, some changes in speed class settings

Potential Methodologies

- Statistical approach (“laissez-faire approach”)
  - Collect data to determine state of practice and derive target values from the results
- Deterministic approach (“AEC approach”)
  - Set EI_T values using the nominal detector dose required to achieve acceptable image quality
- Experimental approach (“phantom approach”)
  - Use geometric or anthropomorphic phantoms to simulate the anatomy of interest

Willis C., Diagnostic SAM session “Considerations and strategies for settings target exposure indicators (EI_T) in digital radiography”, AAPM Annual Meeting, Denver, CO July 31, 2017

Potential Methodologies

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  - Collect data to determine state of practice and derive target values from the results
- Deterministic approach (“AEC approach”)
  - Set EI_T values using the nominal detector dose required to achieve acceptable image quality
- Experimental approach (“phantom approach”)
  - Use geometric or anthropomorphic phantoms to simulate the anatomy of interest

Hybrid Approach: the “slightly less laissez-faire approach?”

Willis C., Diagnostic SAM session “Considerations and strategies for settings target exposure indicators (EI_T) in digital radiography”, AAPM Annual Meeting, Denver, CO July 31, 2017

Preconditions

- EI accuracy has been verified
- AEC has been calibrated to achieve an EI_T corresponding with the nominal recommended detector dose

Questions

- When is appropriate to set EI_T values for an exam group/body part, and when should values be assigned separately for individual views?
  - Keep things as simple as possible (fewer bins is better)!
  - How accurate does EI_T need to be?
    - Considering accuracy of EI (±20%), AEC calibration (±30%?)
- Are there instances when statistics from state of practice should not be used to set EI_T values?

Collect some data!

- The more data points the better
- Include data from more than one site
- Limit sample to units where AEC is known to have been calibrated to a target detector dose using a standardized procedure

We used same dataset as before

- Subset of units selected
- Data exported from:
  - 5 Sites
  - 9 workstations

Make	Model	Count
Shimadzu	**RadSpeed**	**20**
Reliance	ATC 725	5
Shimadzu	Fluoro Speed	3
Quantum	MC 150 Pinnacle	2
Siemens	Multix Top Pro	2
Bennett	Compu-mAs	1
GE	AMX-4	1
Philips	Easy Diagnost Eleva	1
Philips	Optimus	1
Picker	RadView 65	1
Siemens	Sireskop SD	1

- Criteria for selected workstations:
  - Workstation was affiliated with a single radiographic unit and CR reader prior to DR retrofit
  - Workstation was affiliated with a Shimadzu RadSpeeds
- Added 1 additional workstation from site A (ortho clinic) to obtain more data points for extremity work

Collect some data!

↓

Analyze the data at the exam group level

- Start coarse, and get more granular as needed
- Don’t use the vendor’s default EI_T values, normalize all EI values to a reference EI (EI_{ref}) corresponding to the nominal detector dose used for AEC calibration
- For each exam group, calculate the Mean($DI_{ref,k}$), SD($DI_{ref,k}$), Skew($DI_{ref,k}$), and Sample Excess Kurtosis($DI_{ref,k}$)

Collect some data!

↓

Analyze the data at the exam group level

↓

Are the following criteria met?

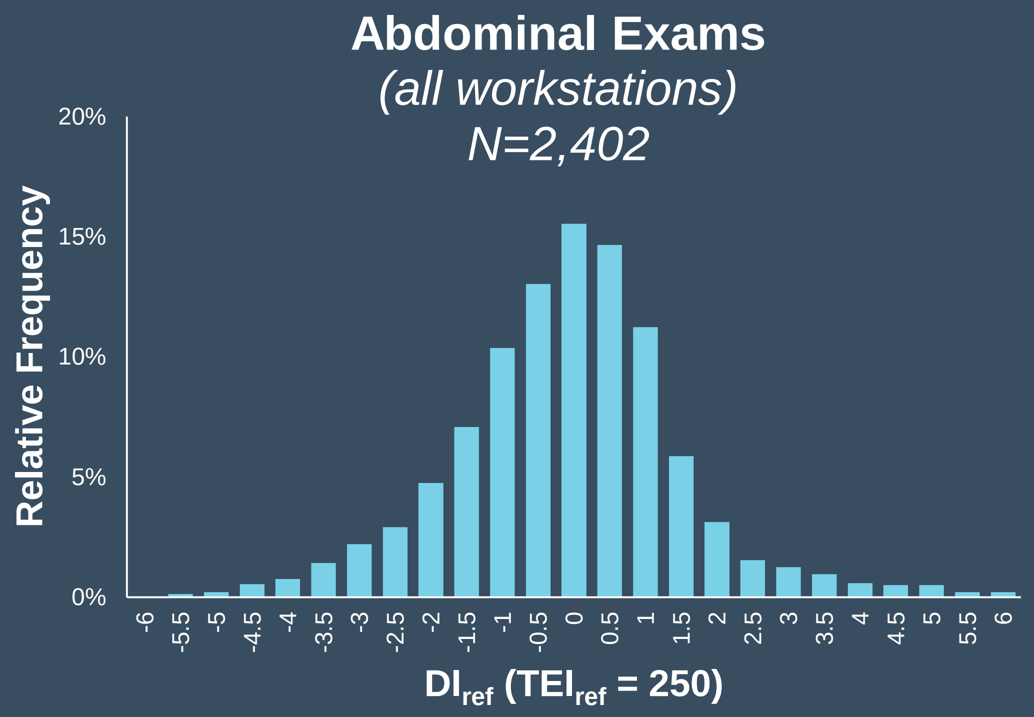
$SD(DI_{ref,k}) < 2.5$*

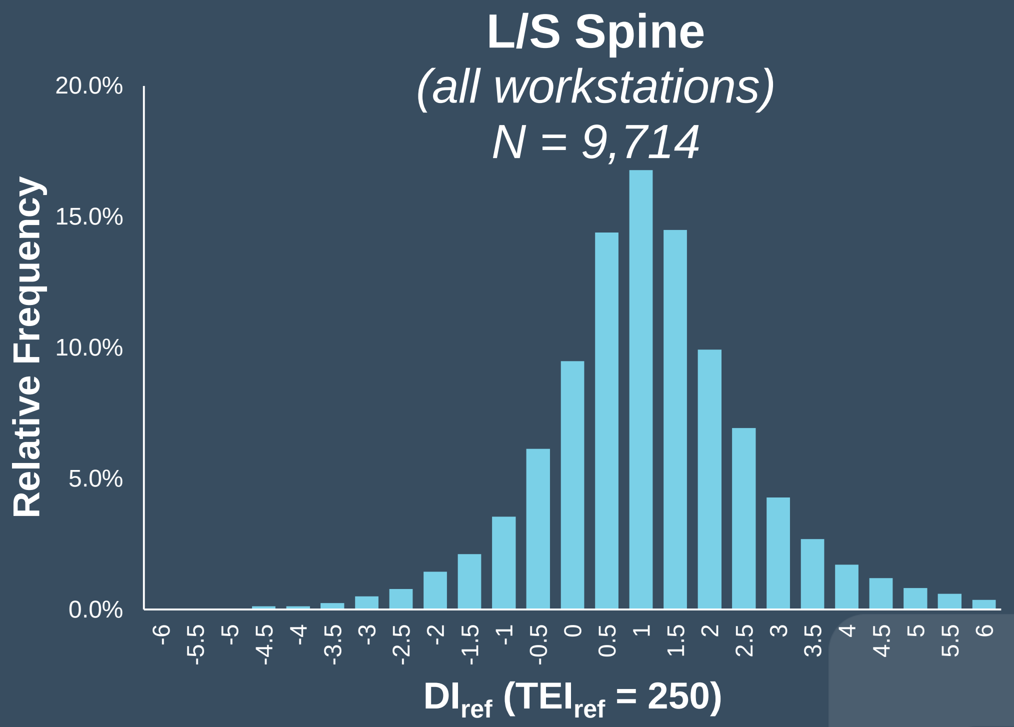
$|Skew(DI_{ref,k})| \leq 1.5$

Sample Excess Kurtosis$(DI_{ref,k}) > 0$

- Note: these criteria worked for our fixed rad rooms with Agfa DR but have not been verified for any other vendor
- *Depending on typical values for the $SD(DI_{ref,k})$ for your facilities, you may need to use a less stringent criteria

When it's easy….





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↓

Analyze the data at the exam group level

↓

Are the following criteria met?

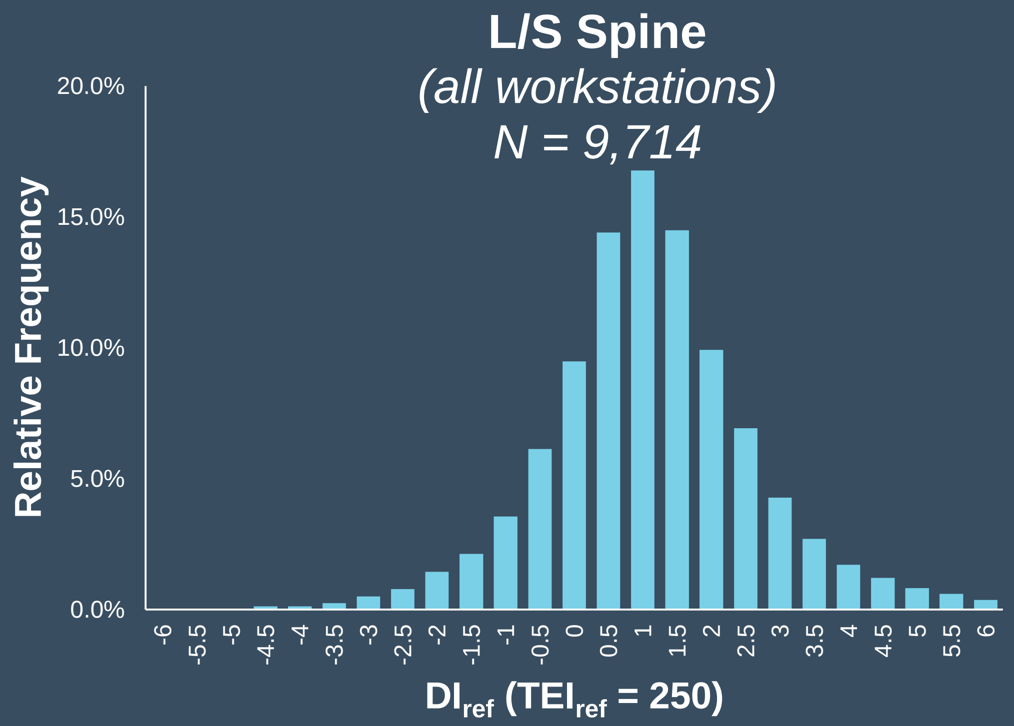
$SD(DI_{ref,k}) < 2.5$*

$|Skew(DI_{ref,k})| \leq 1.5$

Sample Excess Kurtosis$(DI_{ref,k}) > 0$

Remainder of presentation will just use "Kurtosis" to refer to "Sample Excess Kurtosis"

When it's easy….

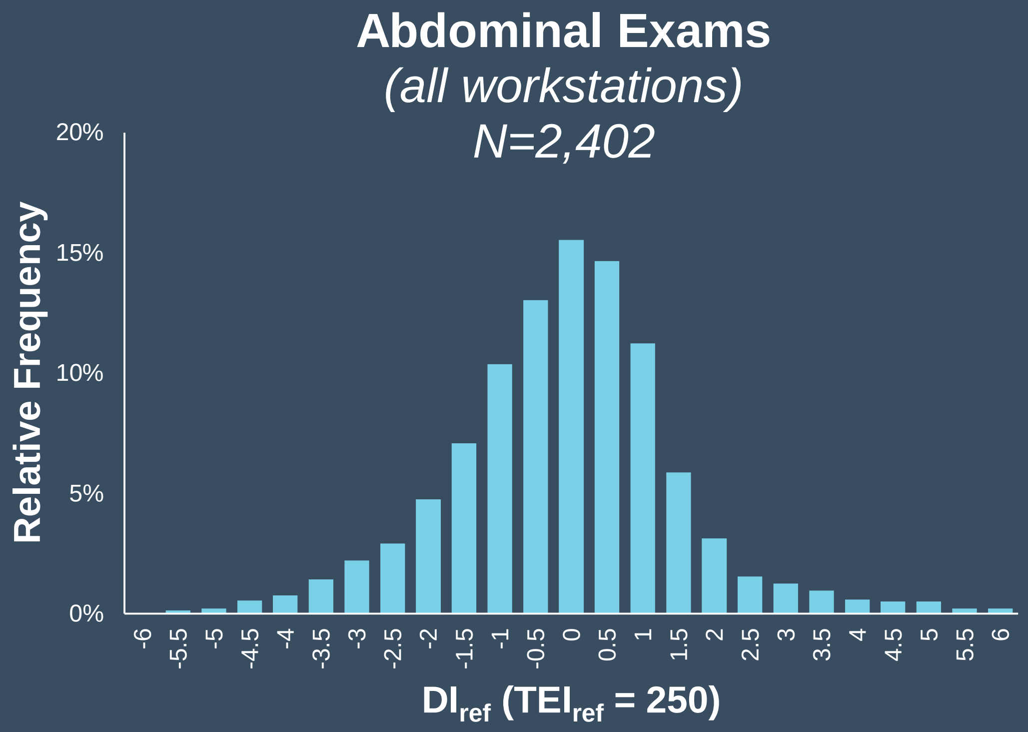


L/S-Spine	All Sites
N	9714
Mean(DI_{ref})	1.19
SD(DI_{ref})	1.70
Skew(DI_{ref})	0.96
Kurtosis(DI_{ref})	4.52
$EI_{ref,k}$	329

Are the following criteria met?

- $SD(DI_{ref,k}) < 2.5$ ✓
- $|Skew(DI_{ref,k})| \leq 1.5$ ✓
- $Kurtosis(DI_{ref,k}) > 0$ ✓

When it’s easy….



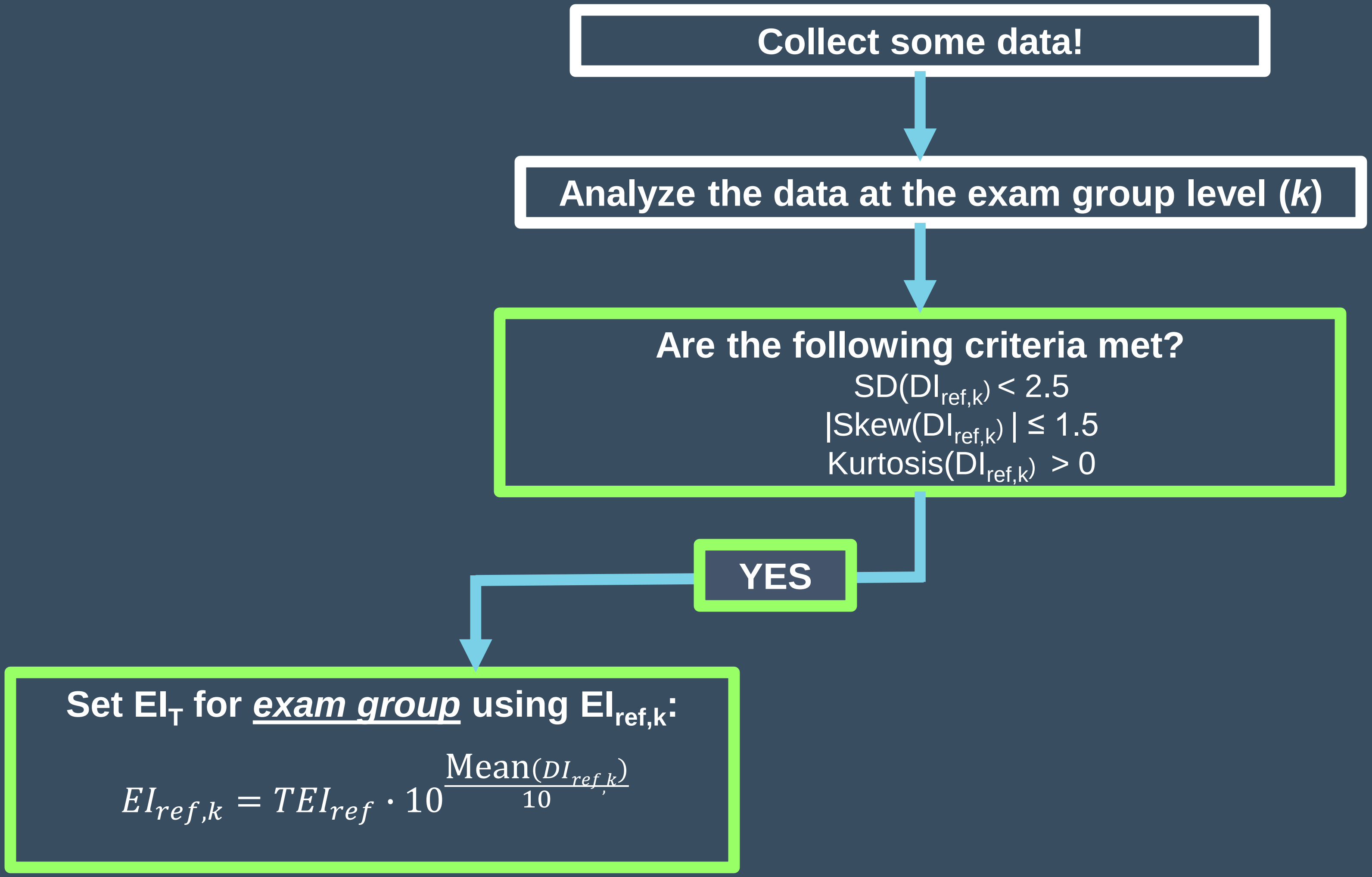
Are the following criteria met?

$SD(DI_{ref,k}) < 2.5$ ✓

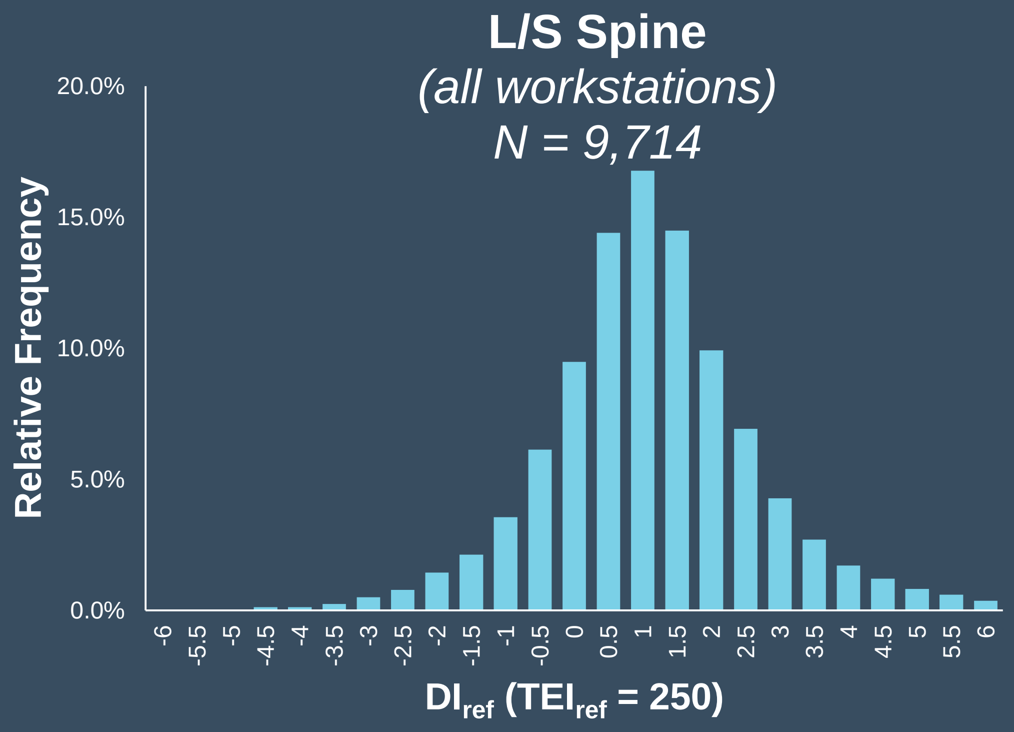
$|Skew(DI_{ref,k})| \leq 1.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

Abdomen	All Sites
N	2402
Mean(DI_{ref})	-0.05
SD(DI_{ref})	1.69
Skew(DI_{ref})	0.70
Kurtosis(DI_{ref})	4.02
$EI_{ref,k}$	247


Collect some data!
Analyze the data at the exam group level (*k*)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$|Skew(DI_{ref,k})| \leq 1.5$
$Kurtosis(DI_{ref,k}) > 0$
YES
Set EI_T for *exam group* using $EI_{ref,k}$:
$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{\text{Mean}(DI_{ref,k})}{10}}$

When it's easy….



Are the following criteria met?

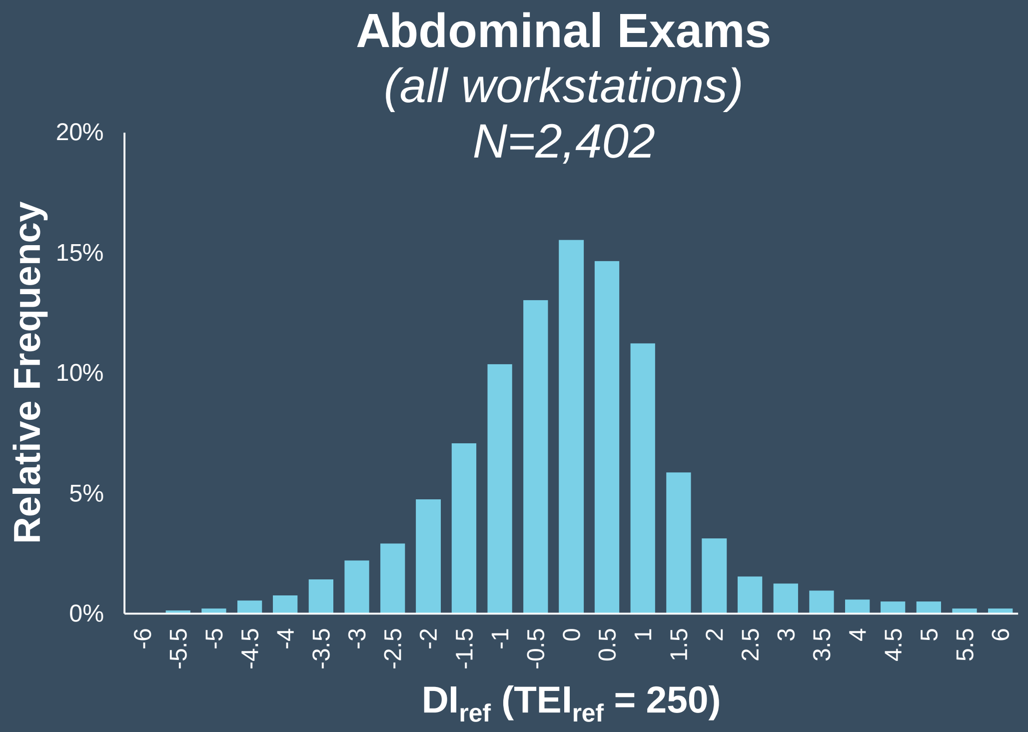
- $SD(DI_{ref,k}) < 2.5$ ✓
- $|Skew(DI_{ref,k})| \leq 1.5$ ✓
- $Kurtosis(DI_{ref,k}) > 0$ ✓

$$EI_{ref,k} = 250 \cdot 10^{\frac{1.19}{10}} = \mathbf{329}$$

$$EI_{T,\ L/S\ Spine} = 330$$

L/S-Spine	All Sites
N	9714
Mean(DI_{ref})	1.19
SD(DI_{ref})	1.70
Skew(DI_{ref})	0.96
Kurtosis(DI_{ref})	4.52
$EI_{ref,k}$	329

When it's easy….



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$EI_{ref,k}$	247

Are the following criteria met?

- $SD(DI_{ref,k}) < 2.5$ ✓
- $|Skew(DI_{ref,k})| \le 1.5$ ✓
- $Kurtosis(DI_{ref,k}) > 0$ ✓

$$EI_{ref,k} = 250 \cdot 10^{\frac{-0.05}{10}} = \mathbf{247}$$

$$EI_{T,\ Abdomen} = 250$$

When it's easy….

Are the following criteria met?

$SD(DI_{ref,k}) < 2.5$ ✓

$|Skew(DI_{ref,k})| \leq 1.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

9 out of 17 exam groups met these criteria:

Exam Group	*N*	Mean(DI_{ref})	SD(DI_{ref})	Skew(DI_{ref})	Kurtosis(DI_{ref})	$EI_{T,k}$*
C-Spine	5490	-0.27	2.56	0.32	0.10	--
Abdomen	2402	-0.05	1.69	0.70	4.02	250
Abdomen GI	152	1.07	2.14	0.54	0.73	
Abdomen GU	501	-0.02	1.86	0.29	0.76	
Chest	15811	-2.06	1.69	1.59	8.06	--
L/S Spine	9714	1.19	1.70	0.96	4.52	330
Pelvis & Hip	15994	1.16	2.34	1.06	2.88	--
Ribs	2353	0.47	2.35	0.03	-0.38	--
Shoulder	13543	0.71	2.62	0.31	0.17	--
T-Spine	1431	0.40	2.57	0.30	-0.15	--
Ankle & Foot	20941	1.55	2.15	0.15	0.56	360
Femur Knee Leg	38498	0.85	2.52	0.62	0.56	--
Hand & Wrist	17368	3.55	2.16	-0.06	2.25	570
Humerus, Elbow & Forearm	5457	3.13	2.06	-0.33	1.76	510
Mandible & TMJ	78	-0.31	2.44	0.46	-0.45	--
Nasal & Orbits	58	0.35	2.46	-0.35	0.36	271
Skull, Sinus & Facial	478	1.26	2.01	-0.43	0.86	334

*Values derived from Mean($D_{ref,k}$) and rounded to nearest 10

When it's easy….

Are the following criteria met?

$SD(DI_{ref,k}) < 2.5$ ✓

$|Skew(DI_{ref,k})| \leq 1.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

9 out of 17 exam groups met these criteria:

Exam Group	*N*	$Mean(DI_{ref})$	$SD(DI_{ref})$	$Skew(DI_{ref})$	$Kurtosis(DI_{ref})$	$EI_{T,k}$*
C-Spine	5490	-0.27	2.56	0.32	0.10	--
Abdomen	2402	-0.05	1.69	0.70	4.02	
Abdomen GI	152	1.07	2.14	0.54	0.73	250
Abdomen GU	501	-0.02	1.86	[illegible]	[illegible]	[illegible]
Chest	15811	-2.06	1.69	[illegible]	[illegible]	[illegible]
L/S Spine	9714	1.19	1.70	[illegible]	[illegible]	[illegible]
Pelvis & Hip	15994	1.16	2.34	[illegible]	[illegible]	[illegible]
Ribs	2353	0.47	2.35	[illegible]	[illegible]	[illegible]
Shoulder	13543	0.71	2.62	[illegible]	[illegible]	[illegible]
T-Spine	1431	0.40	2.57	0.30	-0.15	--
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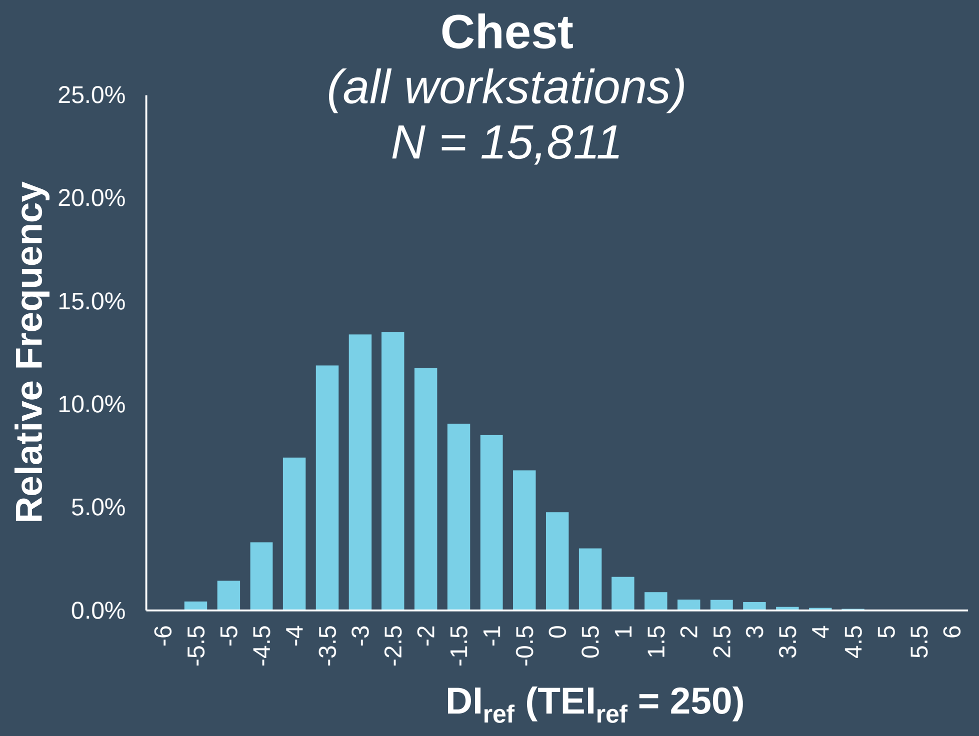
Skull, Sinus & Facial	478	1.26	2.01	-0.43	0.86	334

EI_T values higher than for Ankle and Foot:

- Due to anatomy and value of interest?
- OR, are manual techniques for these exam groups too high?

*Values derived from $Mean(D_{ref,k})$ and rounded to nearest 10

When it's more complicated….



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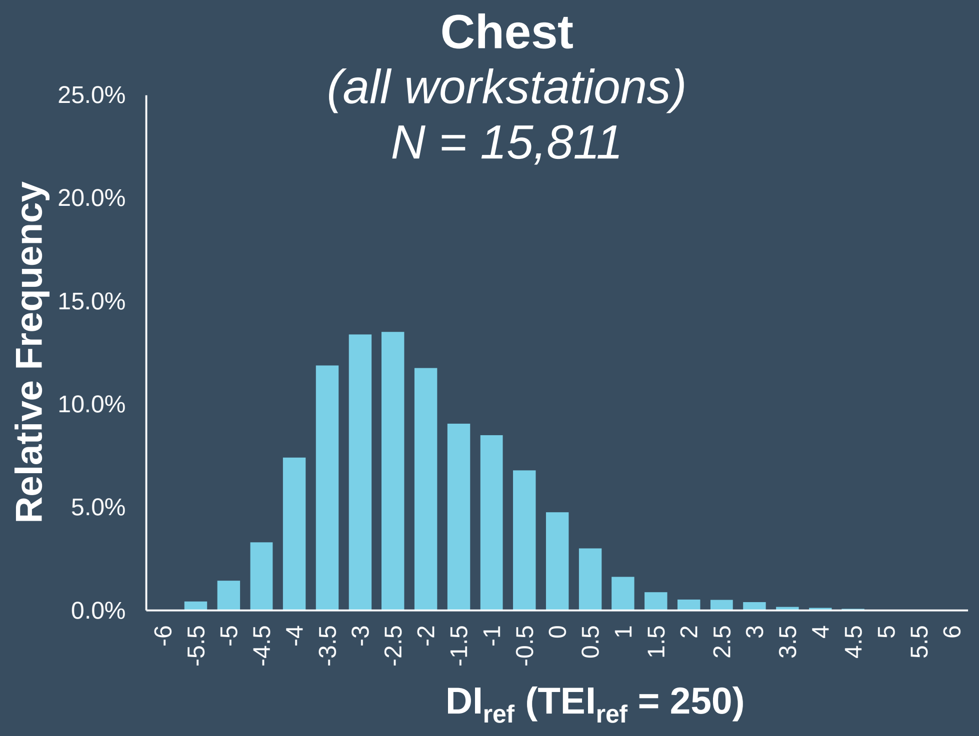

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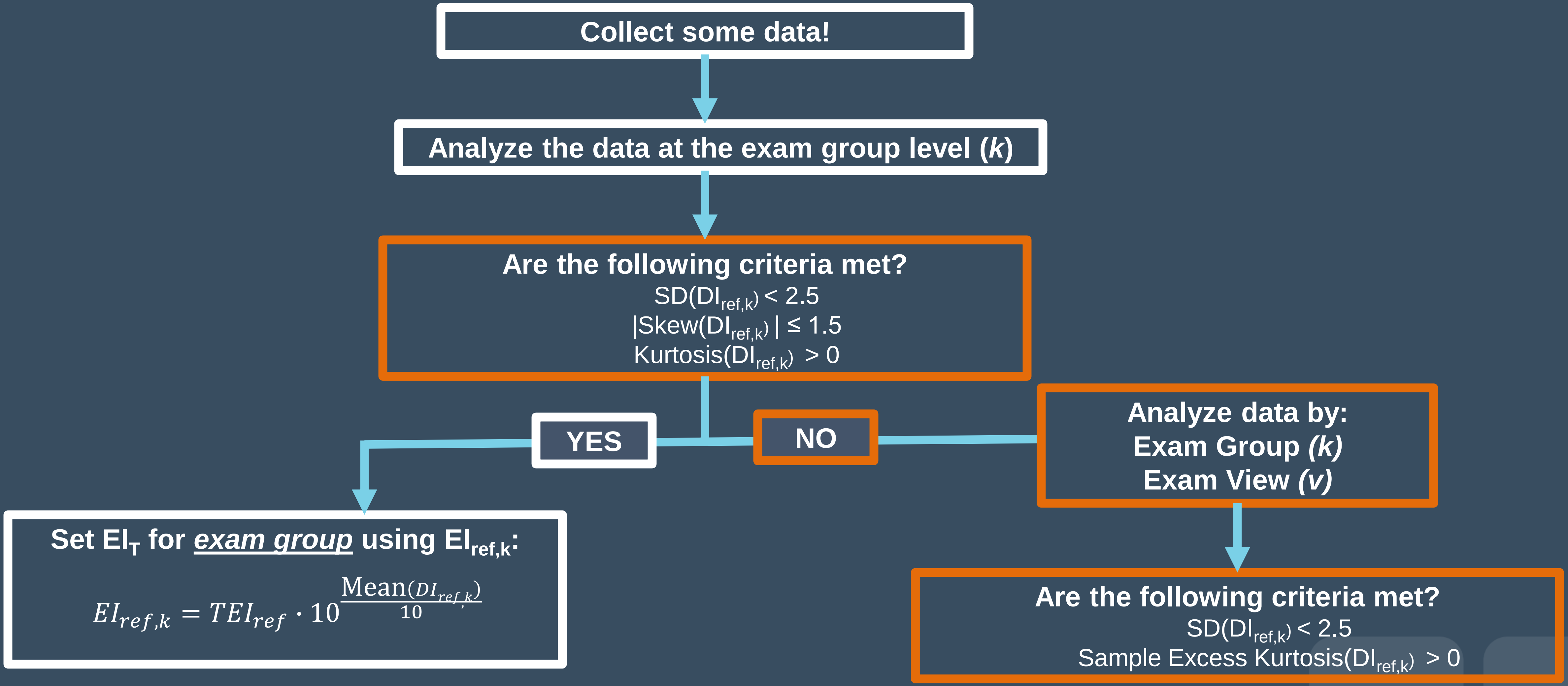
$SD(DI_{ref,k}) < 2.5$

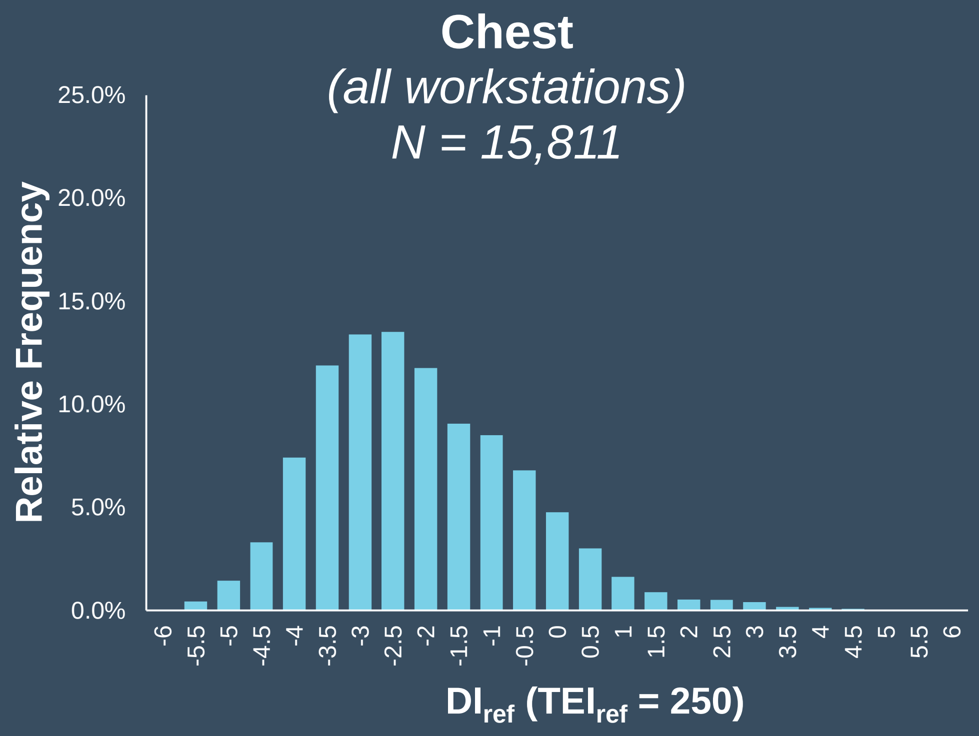
$|Skew(DI_{ref,k})| \leq 1.5$

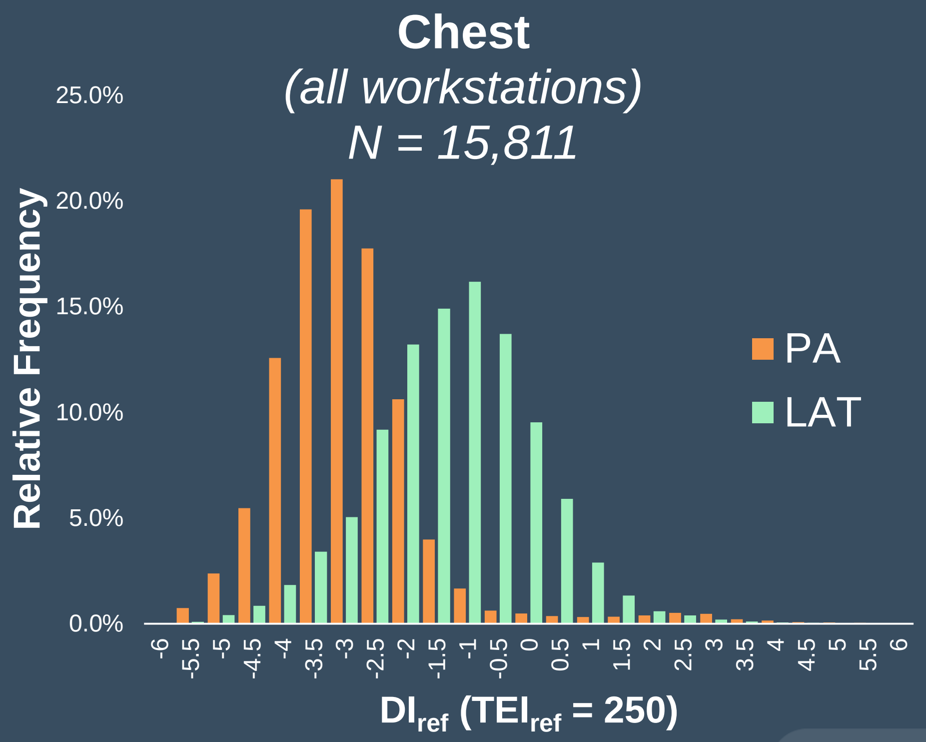
$Kurtosis(DI_{ref,k}) > 0$

Chest	All Sites
N	15811
Mean(DI_{ref})	-2.06
SD(DI_{ref})	1.69
Skew(DI_{ref})	1.59
Kurtosis(DI_{ref})	8.06
$EI_{ref,k}$	155.4


Collect some data!
Analyze the data at the exam group level (*k*)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$|Skew(DI_{ref,k})| \leq 1.5$
$Kurtosis(DI_{ref,k}) > 0$
YES
NO
Analyze data by:
Exam Group (*k*)
Exam View (*v*)
Set EI_T for *exam group* using $EI_{ref,k}$:
$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{\text{Mean}(DI_{ref,k})}{10}}$
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
Sample Excess $Kurtosis(DI_{ref,k}) > 0$

When it's more complicated….





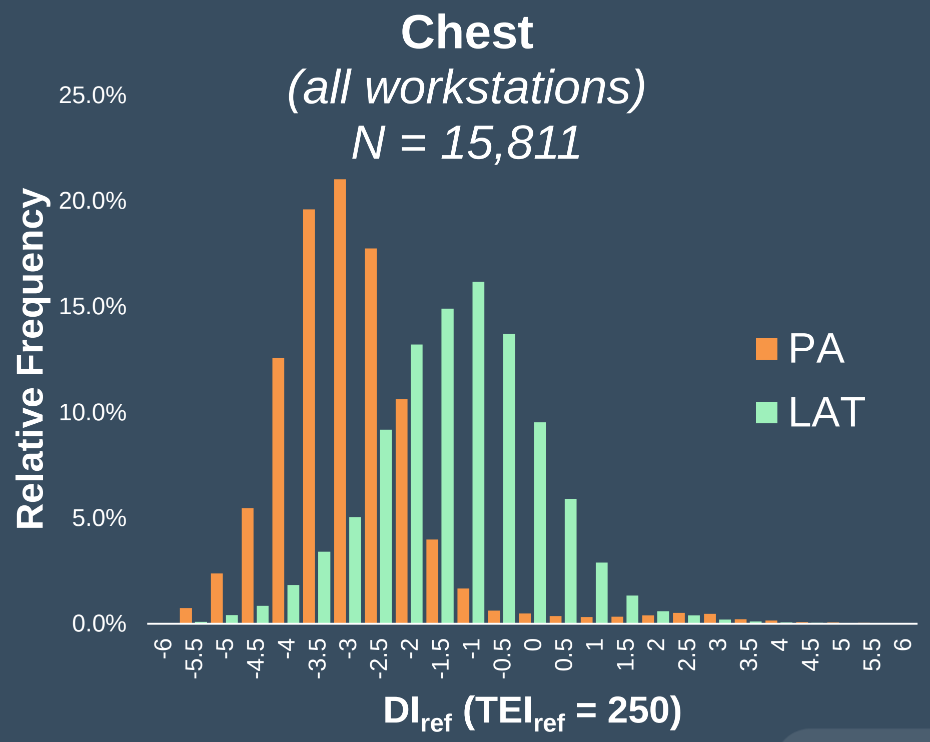
Chest	All Sites	PA Chest Portrait	PA Chest Landscape	LAT Chest
N	15811	2756	5449	7303
Mean(DI_{ref})	-2.06	-2.90	-2.85	-1.22
SD(DI_{ref})	1.69	1.27	1.56	1.40
Skew(DI_{ref})	1.59	3.47	3.68	1.04
Kurtosis(DI_{ref})	8.06	27.10	25.75	8.06
$EI_{ref,k,i}$	155	128	130	189

When it's more complicated….

Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.0$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓



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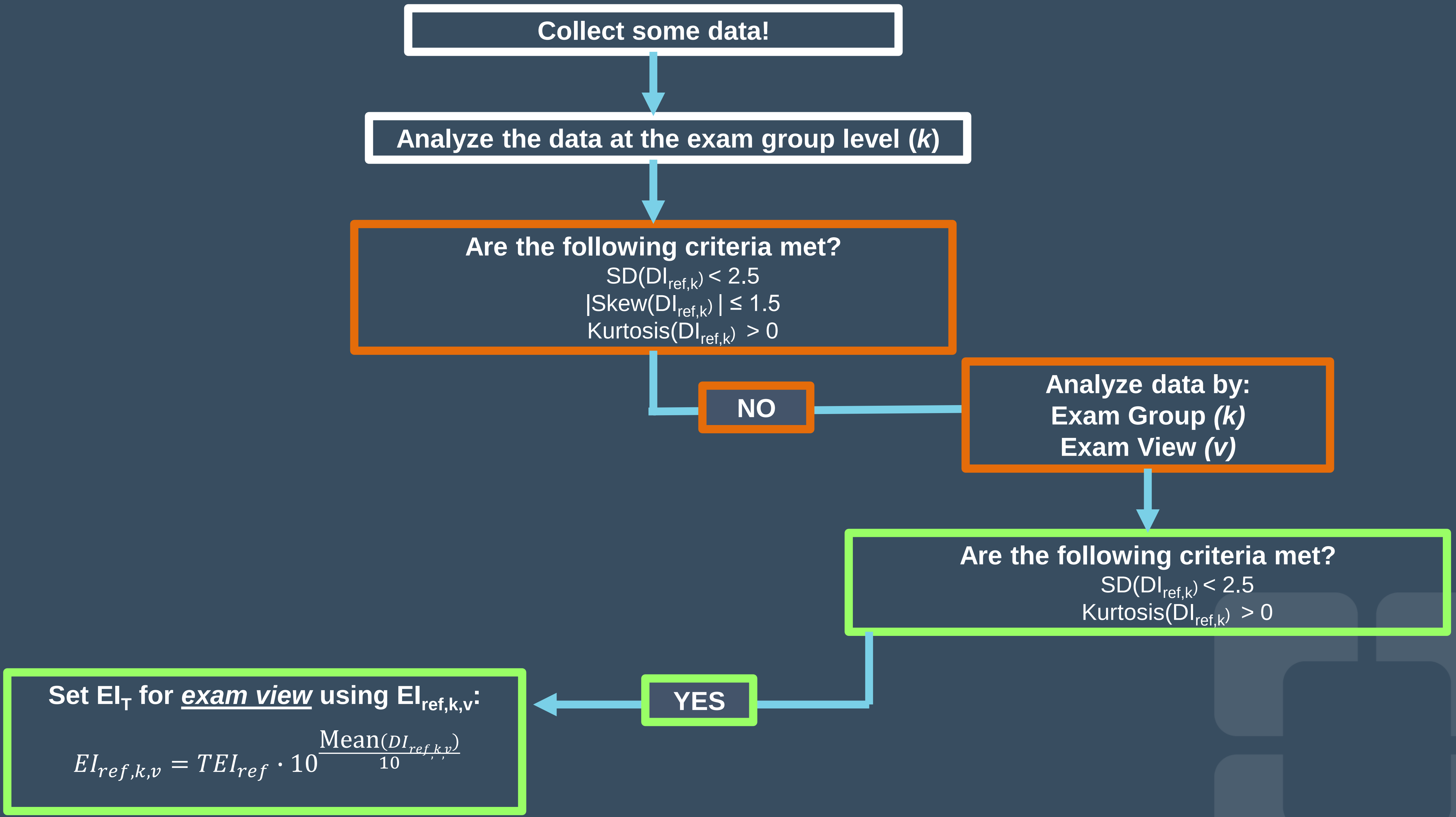


Collect some data!
Analyze the data at the exam group level (*k*)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$|Skew(DI_{ref,k})| \leq 1.5$
$Kurtosis(DI_{ref,k}) > 0$
NO
Analyze data by:
Exam Group (*k*)
Exam View (*v*)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$Kurtosis(DI_{ref,k}) > 0$
YES
Set EI_T for *exam view* using $EI_{ref,k,v}$:
$EI_{ref,k,v} = TEI_{ref} \cdot 10^{\frac{Mean(DI_{ref,k,v})}{10}}$

When it's more complicated….

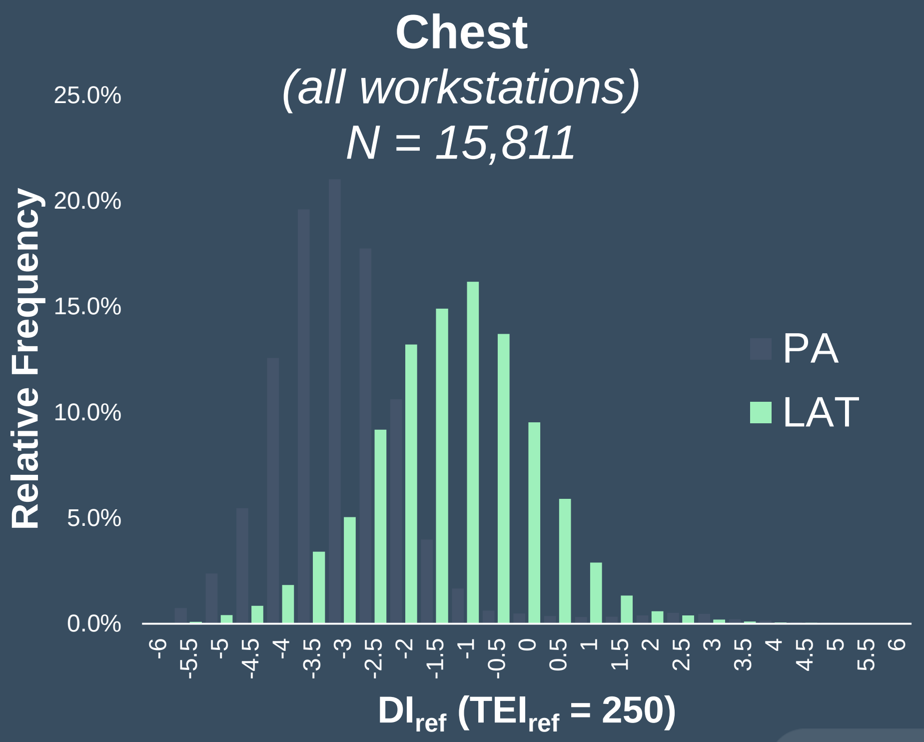
Are the following criteria met?

$SD(DI_{ref,k}) < 2.0$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

$$EI_{ref,k} = 250 \cdot 10^{\frac{-1.22}{10}} = \mathbf{190}$$

$EI_{T,\ LAT\ Chest} = 190$



Chest	All Sites	PA Chest Portrait	PA Chest Landscape	LAT Chest
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$Kurtosis(DI_{ref})$	8.06	27.10	25.75	8.06
$EI_{ref,k,i}$	155	128	130	189

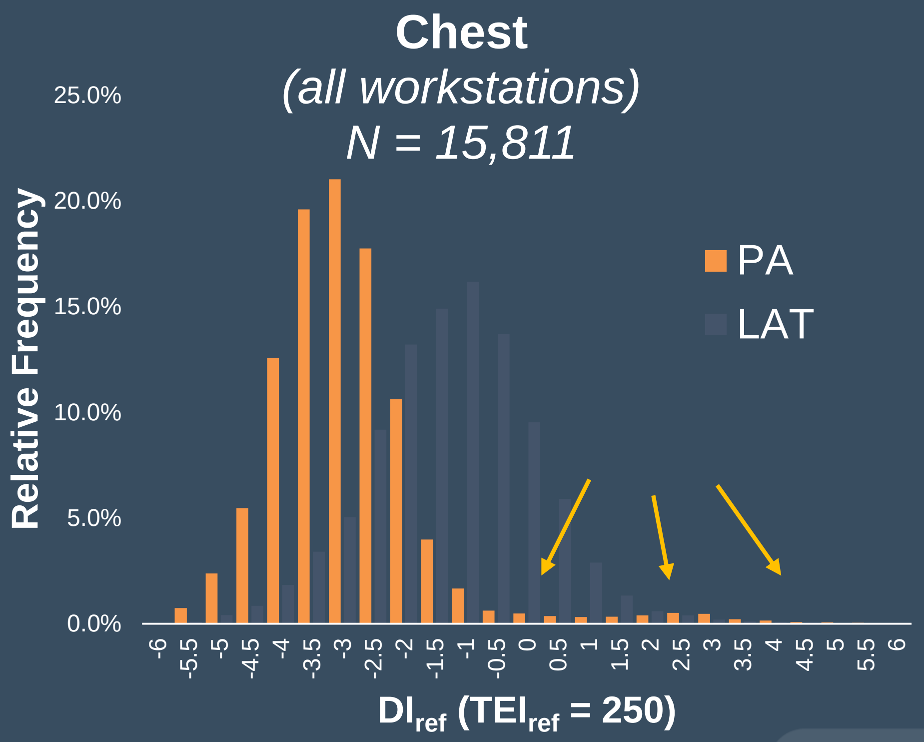
When it's more complicated....

Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

- Skew high for PA Chest due to long right tail
- Further investigation revealed tail due to practice at 2 of the sites
- Mean(DI_{ref}) relatively unaffected by tail, can still set EI_T



When it's more complicated….

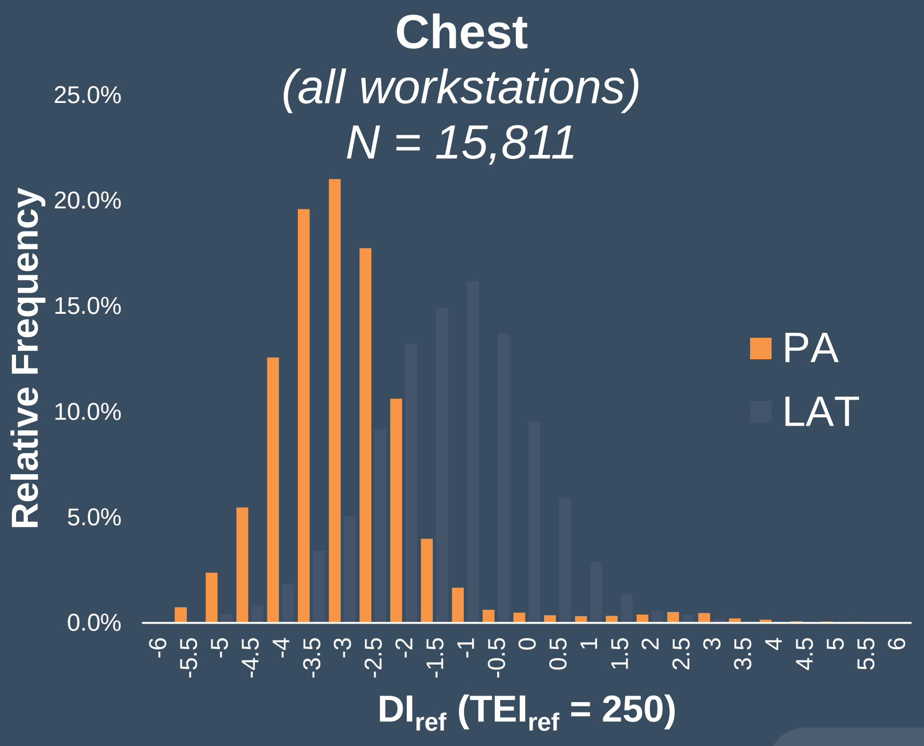
Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

$$EI_{ref,k} = 250 \cdot 10^{\frac{-2.90}{10}} = \mathbf{128}$$

$EI_{T,\ PA\ Chest} = 130$



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$Kurtosis(DI_{ref})$	8.06	27.10	25.75	8.06
$EI_{ref,k,i}$	155	128	130	189

When it's more complicated….

3 out of 17 exam groups fell into this category:

Exam Group	*N*	Mean(DI_{ref})	SD(DI_{ref})	Skew(DI_{ref})	Kurtosis(DI_{ref})	$EI_{T,k}$*
C-Spine	5490	-0.27	2.56	0.32	0.10	--
Abdomen	2402	-0.05	1.69	0.70	4.02	250
Abdomen GI	152	1.07	2.14	0.54	0.73	
Abdomen GU	501	-0.02	1.86	0.29	0.76	
Chest	15811	-2.06	1.69	1.59	8.06	--
L/S Spine	9714	1.19	1.70	0.96	4.52	330
Pelvis & Hip	15994	1.16	2.34	1.06	2.88	--
Ribs	2353	0.47	2.35	0.03	-0.38	--
Shoulder	13543	0.71	2.62	0.31	0.17	--
T-Spine	1431	0.40	2.57	0.30	-0.15	--
Ankle & Foot	20941	1.55	2.15	0.15	0.56	360
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Mandible & TMJ	78	-0.31	2.44	0.46	-0.45	--
Nasal & Orbits	58	0.35	2.46	-0.35	0.36	270
Skull, Sinus & Facial	478	1.26	2.01	-0.43	0.86	330

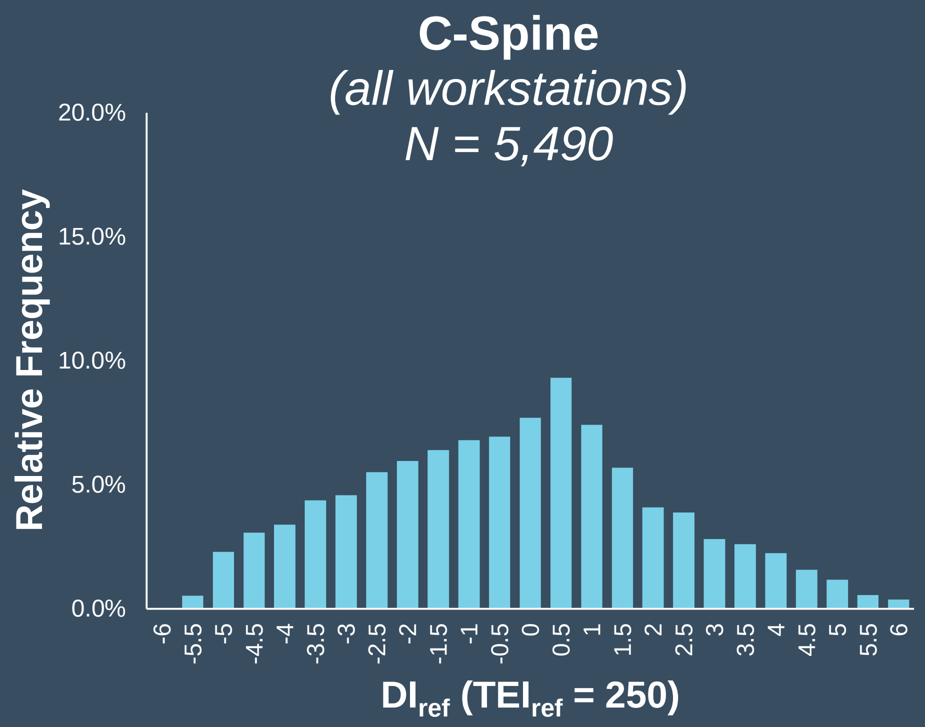
*Values derived from Mean($D_{ref,k}$) and rounded to nearest 10

Example: Chest

Exam Group	View	*N*	Mean(DI_{ref})	SD(DI_{ref})	Skew(DI_{ref})	Kurtosis(DI_{ref})	$EI_{ref,k,i}$	$EI_{T,k,i}$*
Chest	Aggregate	15811	-2.06	1.69	1.59	8.06	--	--
	PA CHEST PORTRAIT	2756	-2.90	1.27	3.47	27.10	128	130
	PA CHEST LANDSCAPE	5449	-2.85	1.56	3.68	25.75	130	
	LORDOTIC CHEST	2	-2.60	--	--	--	138	
	LAT CHEST	7303	-1.22	1.40	1.04	8.06	189	190
	AP CHEST LANDSCAPE	136	-0.77	2.40	0.30	-0.65	209	
	AP CHEST PORTRAIT	93	-1.22	--	--	--	189	
	LAT STERNUM	12	-1.64	--	--	--	171	Larger Sample Size Needed
	OBLI STERNUM	21	-0.18	--	--	--	240	
	OBLI CHEST	4	-0.09	--	--	--	245	
	PA SC JOINT	14	0.34	--	--	--	270	
	OBLI SC JOINT	14	0.69	--	--	--	293	
	DECUB AP CHEST	2	1.54	--	--	--	357	
	DECUB PA CHEST	5	2.92	--	--	--	490	

*Values derived from weighted average of Mean($D_{ref,k,i}$) and rounded to nearest 10

When it's VERY complicated….



Are the following criteria met?

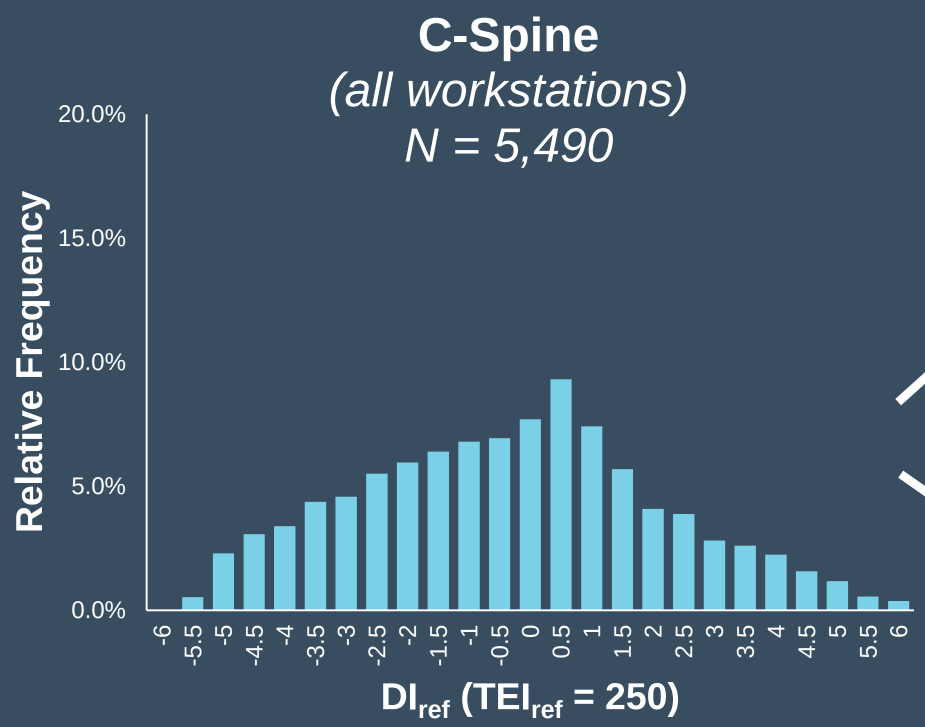
$SD(DI_{ref,k}) < 2.5$ ✗

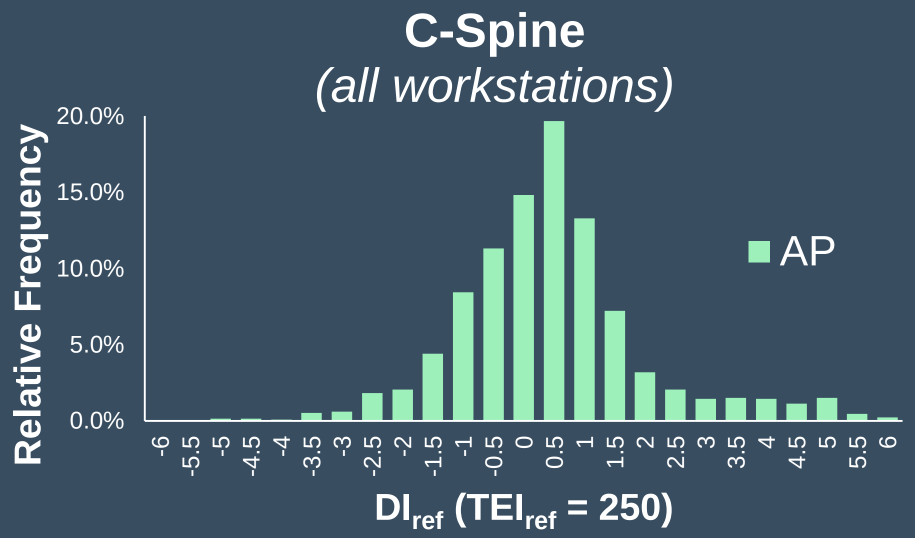
$|Skew(DI_{ref,k})| \leq 1.5$ ✓

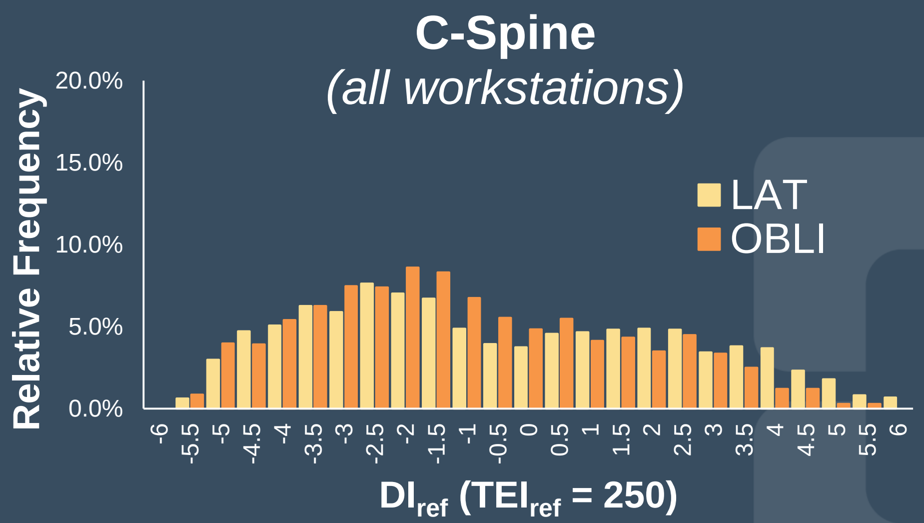
$Kurtosis(DI_{ref,k}) > 0$ ✓

C-Spine	All Sites
N	5490
$Mean(DI_{ref})$	-0.27
$SD(DI_{ref})$	2.56
$Skew(DI_{ref})$	0.32
$Kurtosis(DI_{ref})$	0.10
$EI_{ref,k}$	235.1

Variation between views…





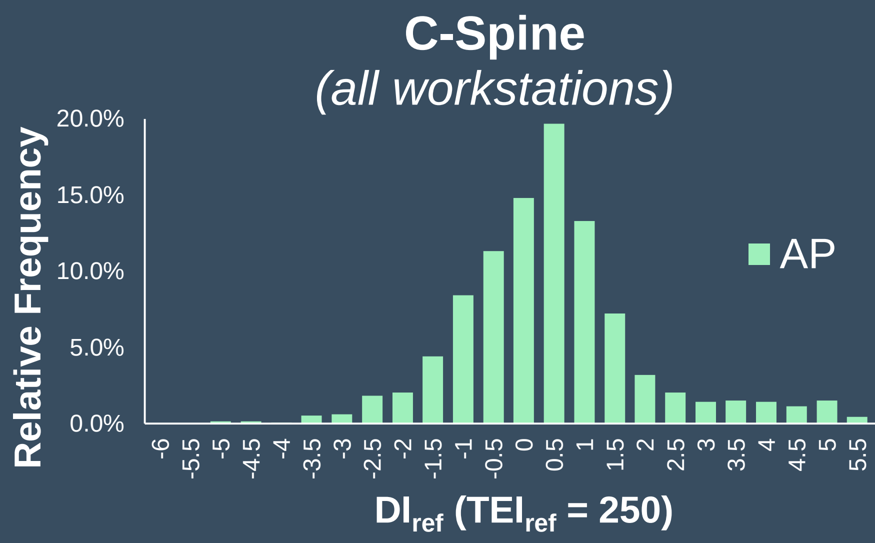


When it's VERY complicated….

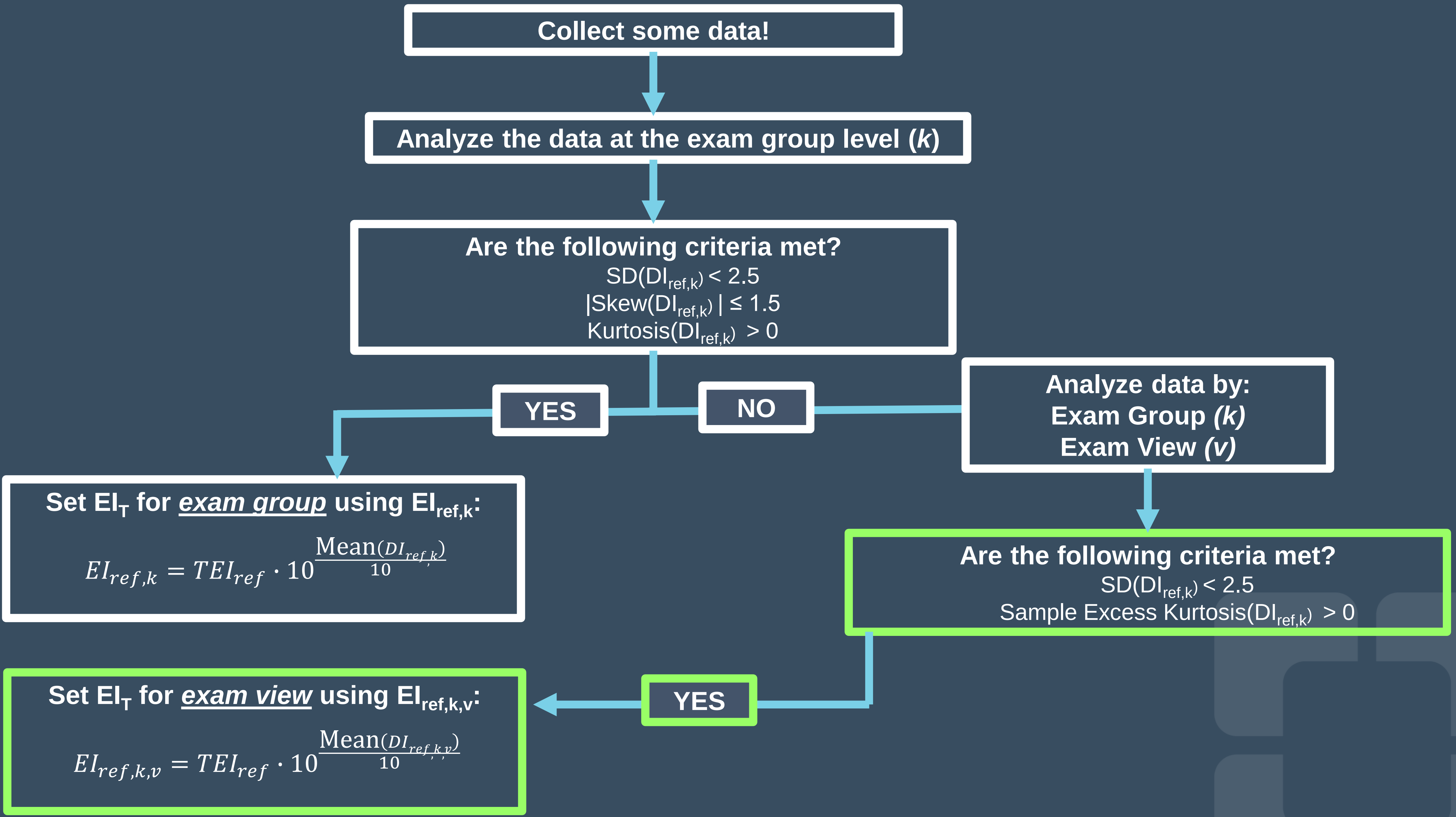
Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓



C-Spine	All Sites	AP C-Spine	LAT C-Spine	OBL C-Spine	OBL C-Spine 2
N	5490	1316	1267	707	700
$Mean(DI_{ref})$	-0.27	0.63	-0.46	-1.03	-1.02
$SD(DI_{ref})$	2.56	1.96	2.91	2.51	2.45
$Skew(DI_{ref})$	0.32	1.69	0.35	0.29	0.42
$Kurtosis(DI_{ref})$	0.10	5.42	-0.93	-0.79	-0.62
$EI_{ref,k,i}$	235.1	247	225	197	198


Collect some data!
Analyze the data at the exam group level (k)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$|Skew(DI_{ref,k})| \leq 1.5$
$Kurtosis(DI_{ref,k}) > 0$
YES
NO
Analyze data by:
Exam Group (k)
Exam View (v)
Set EI_T for exam group using $EI_{ref,k}$:
$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{\mathrm{Mean}(DI_{ref,k})}{10}}$
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
Sample Excess $Kurtosis(DI_{ref,k}) > 0$
YES
Set EI_T for exam view using $EI_{ref,k,v}$:
$EI_{ref,k,v} = TEI_{ref} \cdot 10^{\frac{\mathrm{Mean}(DI_{ref,k,v})}{10}}$

When it's VERY complicated….

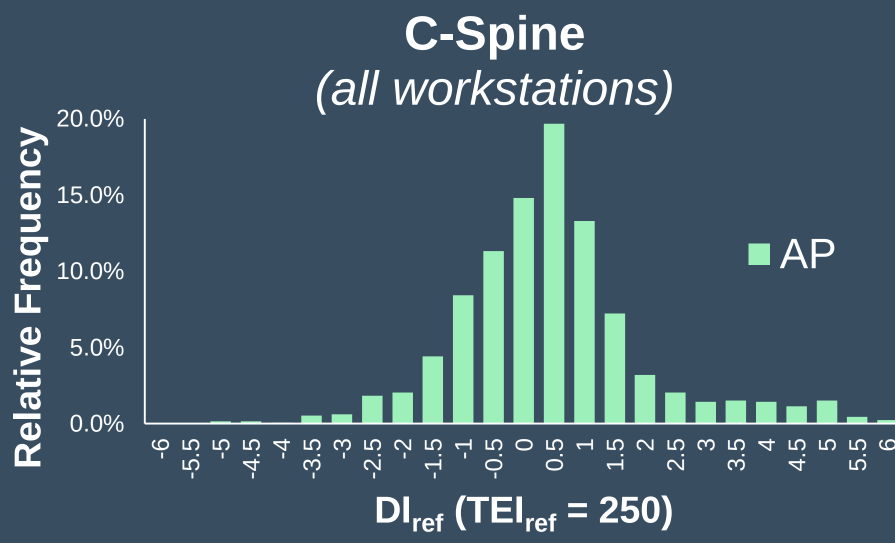
Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.5$ ✓

$Kurtosis(DI_{ref,k}) > 0$ ✓

$$EI_{ref,k} = 250 \cdot 10^{\frac{0.63}{10}} = 289$$

$EI_{T,\ AP\_C\text{-}Spine} = 290$



C-Spine	All Sites	AP C-Spine	LAT C-Spine	OBL C-Spine	OBL C-Spine 2
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$Kurtosis(DI_{ref})$	0.10	5.42	-0.93	-0.79	-0.62
$EI_{ref,k,i}$	235.1	289	225	197	198

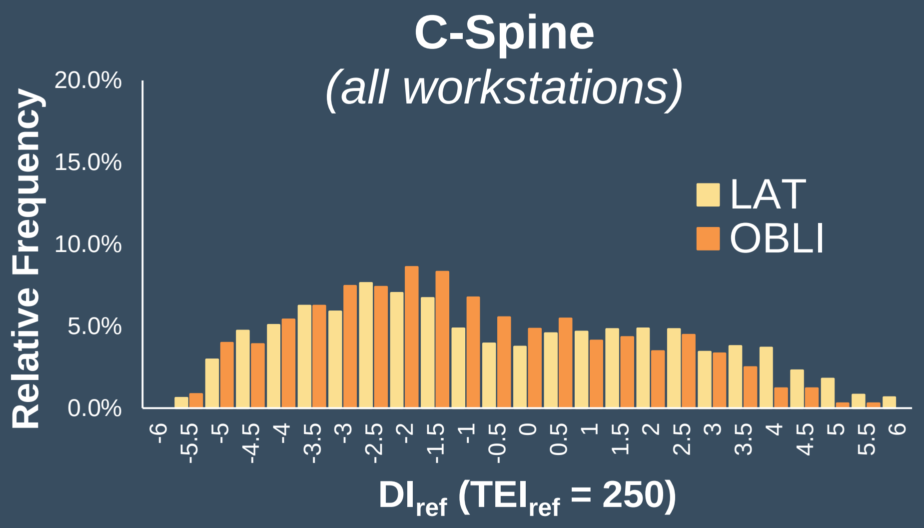
When it's VERY complicated….

Are the following criteria met (@ view level)?

$SD(DI_{ref,k}) < 2.5$ ✗

$Kurtosis(DI_{ref,k}) > 0$ ✗

Basically, it's a mess….
Have a bit of work to do before can set EI_T values for these views!



C-Spine	All Sites	AP C-Spine	LAT C-Spine	OBL C-Spine	OBL C-Spine 2
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$Mean(DI_{ref})$	-0.27	0.63	-0.46	-1.03	-1.02
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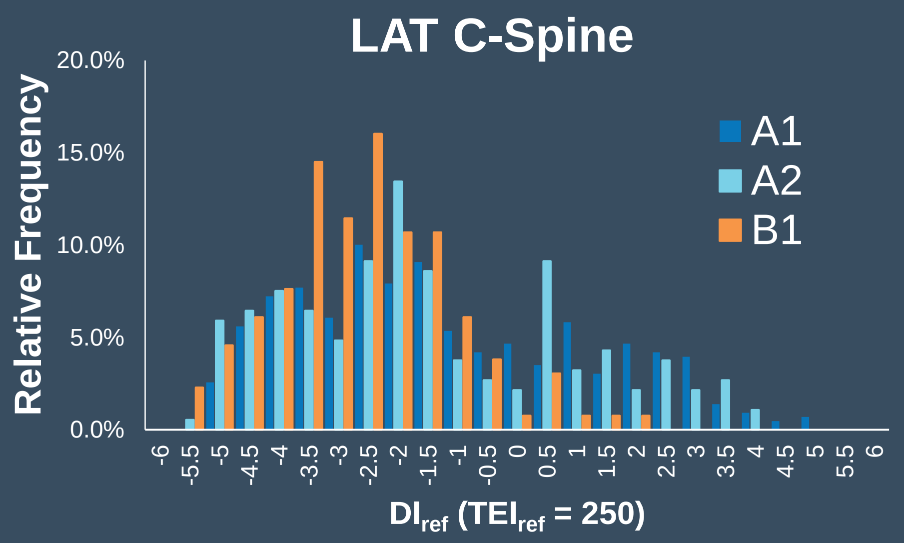
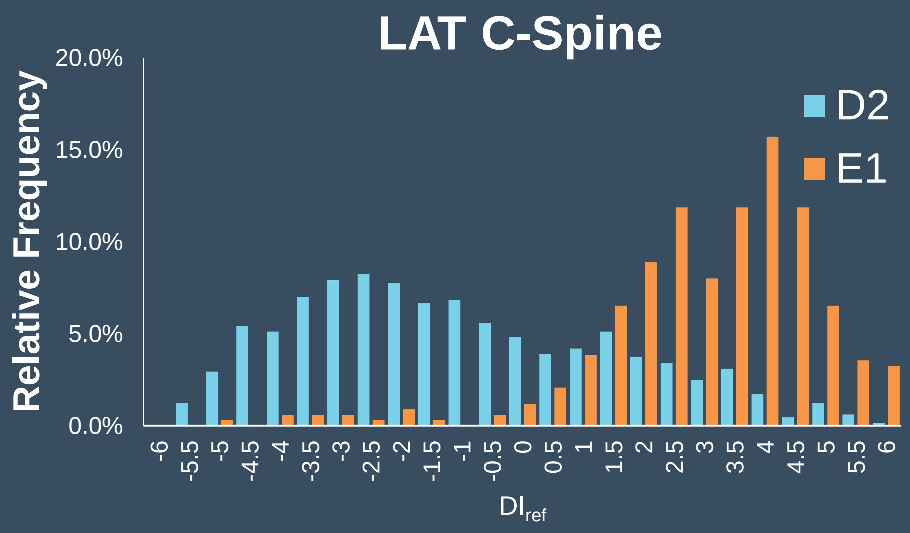
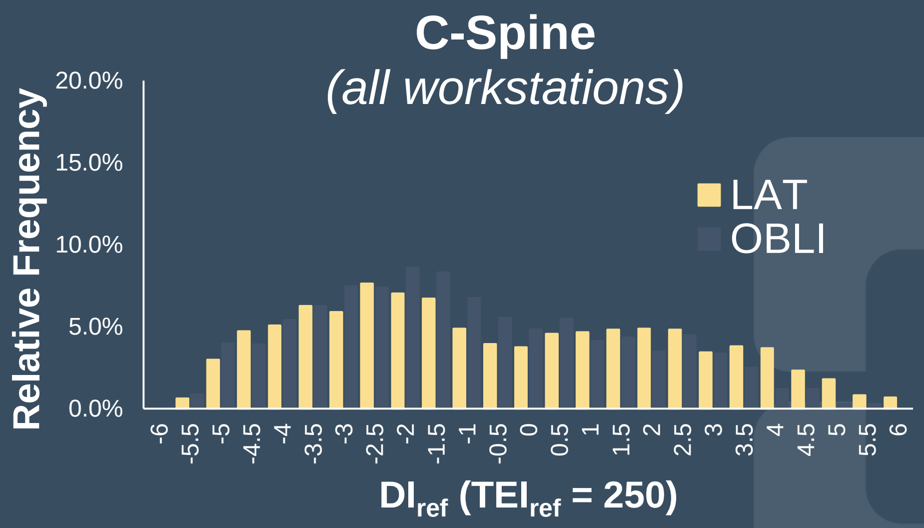
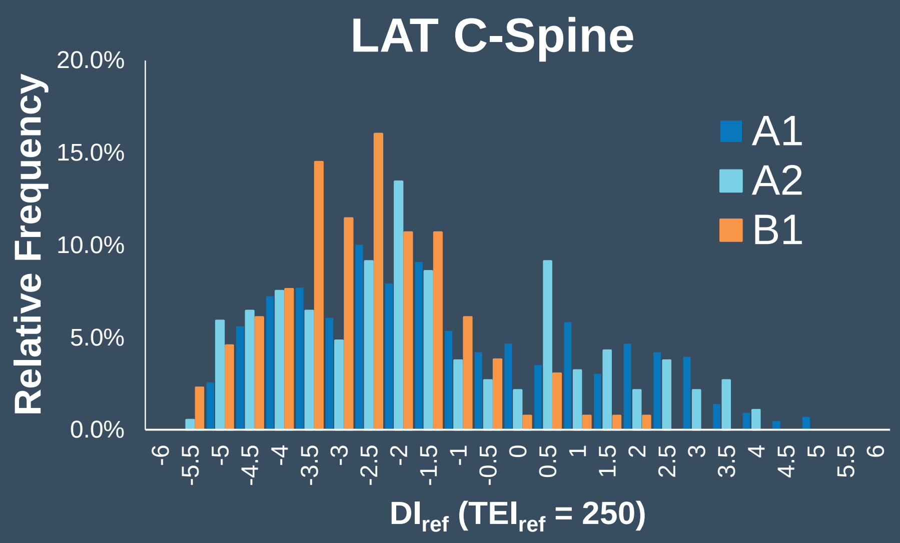
Variation between sites…

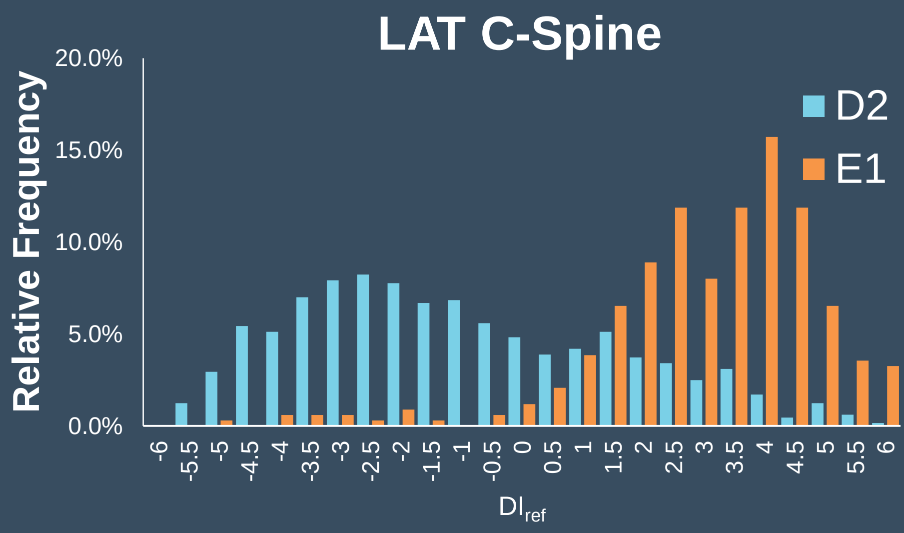






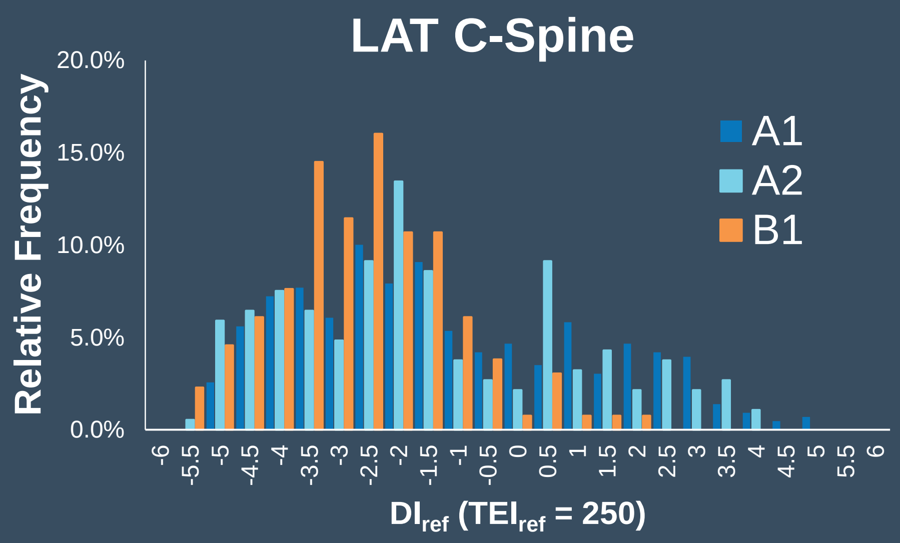
Variation between sites…

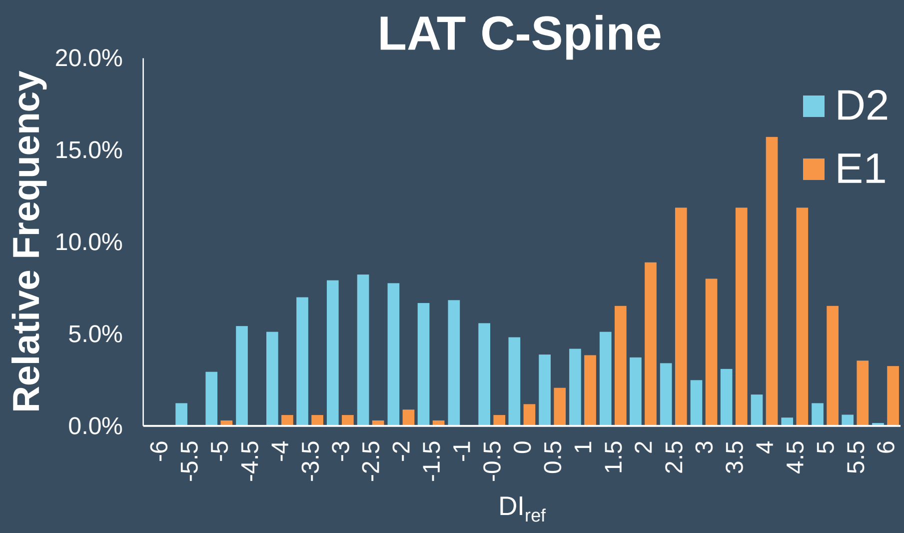




LAT C-Spine	All Sites	A1	A2	A3	B1	C1	C2	D1	D2	E1
N	1267	241	125	30	103	64	63	2	421	218
Mean(DI_{ref})	-0.46	-1.12	-1.50	-0.13	-2.55	-2.25	0.25	0.20	-1.05	3.24
SD(DI_{ref})	2.91	2.48	2.22	2.17	1.49	1.94	2.20	0.61	2.64	1.86
Skew(DI_{ref})	0.35	0.45	0.43	-0.14	0.55	0.34	0.27	--	0.55	-1.49
Kurtosis(DI_{ref})	-0.93	-0.65	-0.58	-0.78	0.30	-0.88	0.09	--	-0.45	3.65
$EI_{ref,k}$	225	193	177	243	139	149	265	262	196	527

Variation between sites…





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N	1267	241	125	30	103	64	63	2	421	218
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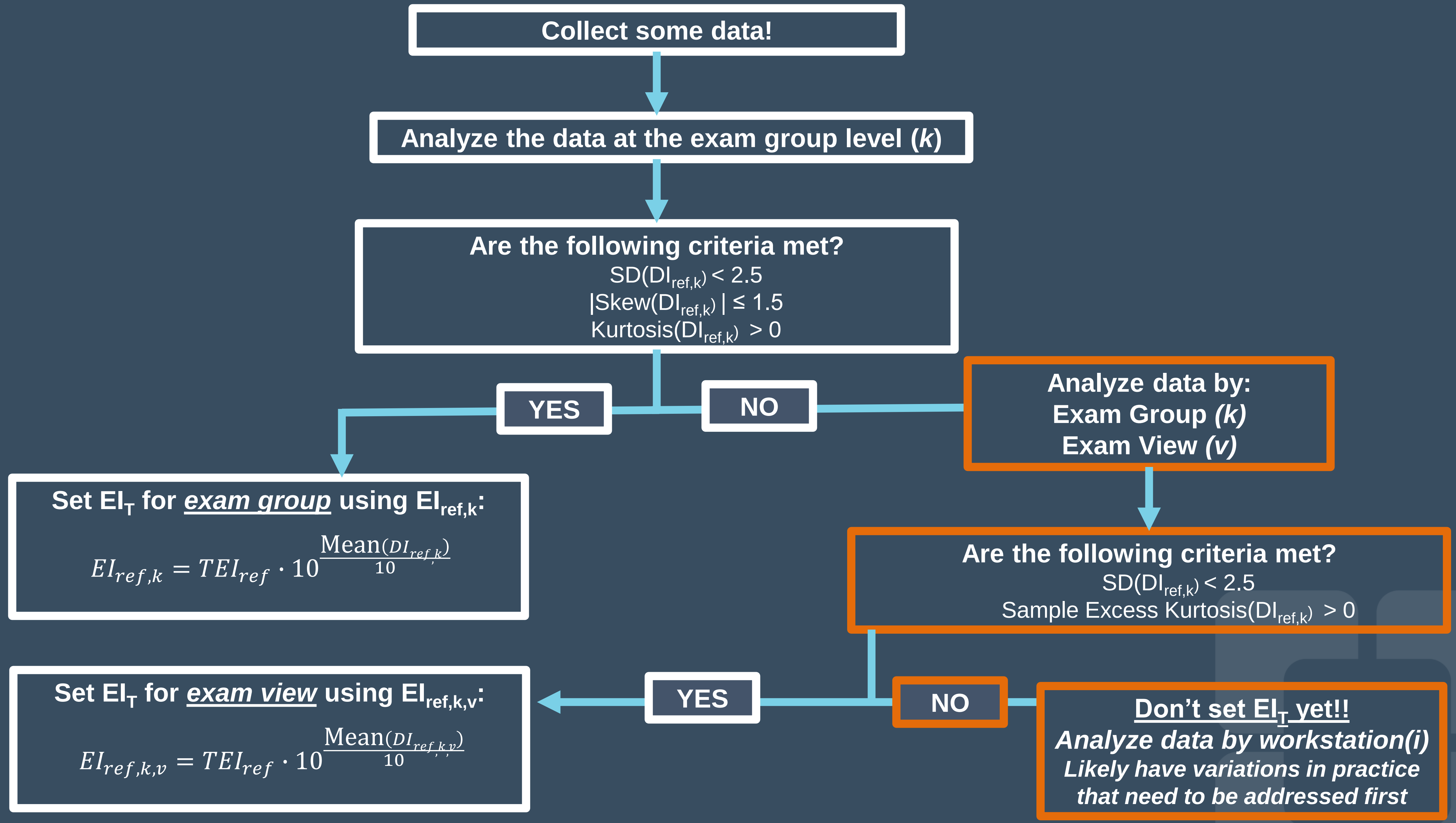
SD(DI_{ref})	2.91	2.48	2.22	2.17	1.49	1.94	2.20	0.61	2.64	1.86
Skew(DI_{ref})	0.35	0.45	0.43	-0.14	0.55	0.34	0.27	--	0.55	-1.49
Kurtosis(DI_{ref})	-0.93	-0.65	-0.58	-0.78	0.30	-0.88	0.09	--	-0.45	3.65
$EI_{ref,k}$	225	193	177	243	139	149	265	262	196	527

Techniques for site E1 ~4X higher than site B1!! – is E1 too high? Or is B1 too low?


Collect some data!
Analyze the data at the exam group level (k)
Are the following criteria met?
SD(DI_ref,k) < 2.5
|Skew(DI_ref,k) | ≤ 1.5
Kurtosis(DI_ref,k) > 0
YES
NO
Analyze data by:
Exam Group (k)
Exam View (v)
Set EI_T for exam group using EI_ref,k:
$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{\text{Mean}(DI_{ref,k})}{10}}$
Are the following criteria met?
SD(DI_ref,k) < 2.5
Sample Excess Kurtosis(DI_ref,k) > 0
YES
NO
Set EI_T for exam view using EI_ref,k,v:
$EI_{ref,k,v} = TEI_{ref} \cdot 10^{\frac{\text{Mean}(DI_{ref,k,v})}{10}}$
Don’t set EI_T yet!!
Analyze data by workstation(i)
Likely have variations in practice
that need to be addressed first

Exam groups needing further investigation:

5 out of 17 exam groups:

Exam Group	*N*	Mean(DI_{ref})	SD(DI_{ref})	Skew(DI_{ref})	Kurtosis(DI_{ref})	$EI_{T,k}$*
C-Spine	5490	-0.27	2.56	0.32	0.10	--
Abdomen	2402	-0.05	1.69	0.70	4.02	250
Abdomen GI	152	1.07	2.14	0.54	0.73	
Abdomen GU	501	-0.02	1.86	0.29	0.76	
Chest	15811	-2.06	1.69	1.59	8.06	--
L/S Spine	9714	1.19	1.70	0.96	4.52	330
Pelvis & Hip	15994	1.16	2.34	1.06	2.88	--
Ribs	2353	0.47	2.35	0.03	-0.38	--
Shoulder	13543	0.71	2.62	0.31	0.17	--
T-Spine	1431	0.40	2.57	0.30	-0.15	--
Ankle & Foot	20941	1.55	2.15	0.15	0.56	360
Femur Knee Leg	38498	0.85	2.52	0.62	0.56	--
Hand & Wrist	17368	3.55	2.16	-0.06	2.25	570
Humerus, Elbow & Forearm	5457	3.13	2.06	-0.33	1.76	510
Mandible & TMJ	78	-0.31	2.44	0.46	-0.45	--
Nasal & Orbits	58	0.35	2.46	-0.35	0.36	270
Skull, Sinus & Facial	478	1.26	2.01	-0.43	0.86	330

(i.e. we still have some work to do….)

EI_T values established so far:

<table>
<tr><th>Exam Group</th><th>View(s)</th><th>N</th><th>SD(DI_{ref})</th><th>$EI_{T,k,i}$</th></tr>
<tr><td>Abdomen</td><td>All</td><td>2402</td><td>1.69</td><td rowspan="3">250</td></tr>
<tr><td>Abdomen GI</td><td>All</td><td>152</td><td>2.14</td></tr>
<tr><td>Abdomen GU</td><td>All</td><td>501</td><td>1.86</td></tr>
<tr><td rowspan="6">Chest</td><td>PA CHEST PORTRAIT</td><td>2756</td><td>1.27</td><td rowspan="3">130</td></tr>
<tr><td>PA CHEST LANDSCAPE</td><td>5449</td><td>1.56</td></tr>
<tr><td>LORDOTIC CHEST</td><td>2</td><td>--</td></tr>
<tr><td>LAT CHEST</td><td>7303</td><td>1.40</td><td rowspan="3">190</td></tr>
<tr><td>AP CHEST LANDSCAPE</td><td>136</td><td>2.40</td></tr>
<tr><td>AP CHEST PORTRAIT</td><td>93</td><td>--</td></tr>
<tr><td>L/S Spine</td><td>All</td><td>9714</td><td>1.70</td><td>330</td></tr>
<tr><td rowspan="6">Pelvis and Hip</td><td>AP HIP</td><td>4142</td><td>1.84</td><td rowspan="6">310</td></tr>
<tr><td>INLET VIEW PELVIS</td><td>63</td><td>2.04</td></tr>
<tr><td>AP PELVIS</td><td>6430</td><td>1.87</td></tr>
<tr><td>AP SI JOINTS</td><td>75</td><td>2.10</td></tr>
<tr><td>LAT FROG</td><td>3311</td><td>2.44</td></tr>
<tr><td>OUTLET VIEW PELVIS</td><td>67</td><td>2.30</td></tr>
<tr><td rowspan="6">T-Spine</td><td>LAT T-SPINE</td><td>735</td><td>1.92</td><td rowspan="4">180</td></tr>
<tr><td>OBLI T-SPINE 2</td><td>1</td><td>--</td></tr>
<tr><td>LAT T-L SPINE</td><td>2</td><td>--</td></tr>
<tr><td>OBLI T-SPINE</td><td>2</td><td>--</td></tr>
<tr><td>AP T-SPINE</td><td>689</td><td>1.77</td><td rowspan="2">420</td></tr>
<tr><td>AP T-L SPINE</td><td>2</td><td>--</td></tr>
<tr><td>Ankle & Foot</td><td>All</td><td>20941</td><td>2.15</td><td>360</td></tr>
<tr><td>Hand & Wrist</td><td>All</td><td>17368</td><td>2.16</td><td>570</td></tr>
<tr><td>Humerus, Elbow & Forearm</td><td>All</td><td>5457</td><td>2.06</td><td>510</td></tr>
<tr><td>Nasal & Orbits</td><td>All</td><td>58</td><td>2.46</td><td>270</td></tr>
<tr><td>Skull, Sinus & Facial</td><td>All</td><td>478</td><td>2.01</td><td>300</td></tr>
</table>

Next Steps

- Investigate the 5 exam groups flagged for further investigation
  - May require collecting additional data
- Provide final list of EI_T values to applications – update EI_T values for initial NX station, then import settings to remaining NX stations
- Setting EI_T likely an iterative process, but we'd like do it as few times as possible…

Next Steps

- Set recommended action limits for our technologists using the SD in DI

Exam Group	View(s)	*N*	$SD(DI_{ref})$	$EI_{T,k,i}$
Abdomen	All	2402	1.69	250
Abdomen GI	All	152	2.14	
Abdomen GU	All	501	1.86	
Chest	PA CHEST PORTRAIT	2756	1.27	130
	PA CHEST LANDSCAPE	5449	1.56	
	LORDOTIC CHEST	2	--	
	LAT CHEST	7303	1.40	190
	AP CHEST LANDSCAPE	136	2.40	
	AP CHEST PORTRAIT	93	--	
L/S Spine	All	9714	1.70	330
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	INLET VIEW PELVIS	63	2.04	
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	AP SI JOINTS	75	2.10	
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	OUTLET VIEW PELVIS	67	2.30	
T-Spine	LAT T-SPINE	735	1.92	180
	OBLI T-SPINE 2	1	--	
	LAT T-L SPINE	2	--	
	OBLI T-SPINE	2	--	
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Ankle & Foot	All	20941	2.15	360
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Humerus, Elbow & Forearm	All	5457	2.06	510
Nasal & Orbits	All	58	2.46	270
Skull, Sinus & Facial	All	478	2.01	300

Weighted average for $SD(DI_{ref}) = 1.9$

Next Steps

- Set recommended action limits for our technologists using the SD in DI
  - Weighted average for $SD(DI_{ref}) = 1.9$

	DI	Action
> 2*SD	DI > 4	See fault tree Fig 7
> 1*SD	2.1 < DI < 3.9	Log for possible review, tally number of occurrences for periodic review
	-2.0 < DI < 2.0	--
< 1*SD	-3.9 < DI < 2.1	Log for possible review, tally number of occurrences for periodic review
< 2*SD	DI < -4	See fault tree Fig 8

Might be too stringent as a starting point?

Especially if want to use single table for all exams/views

Next Steps

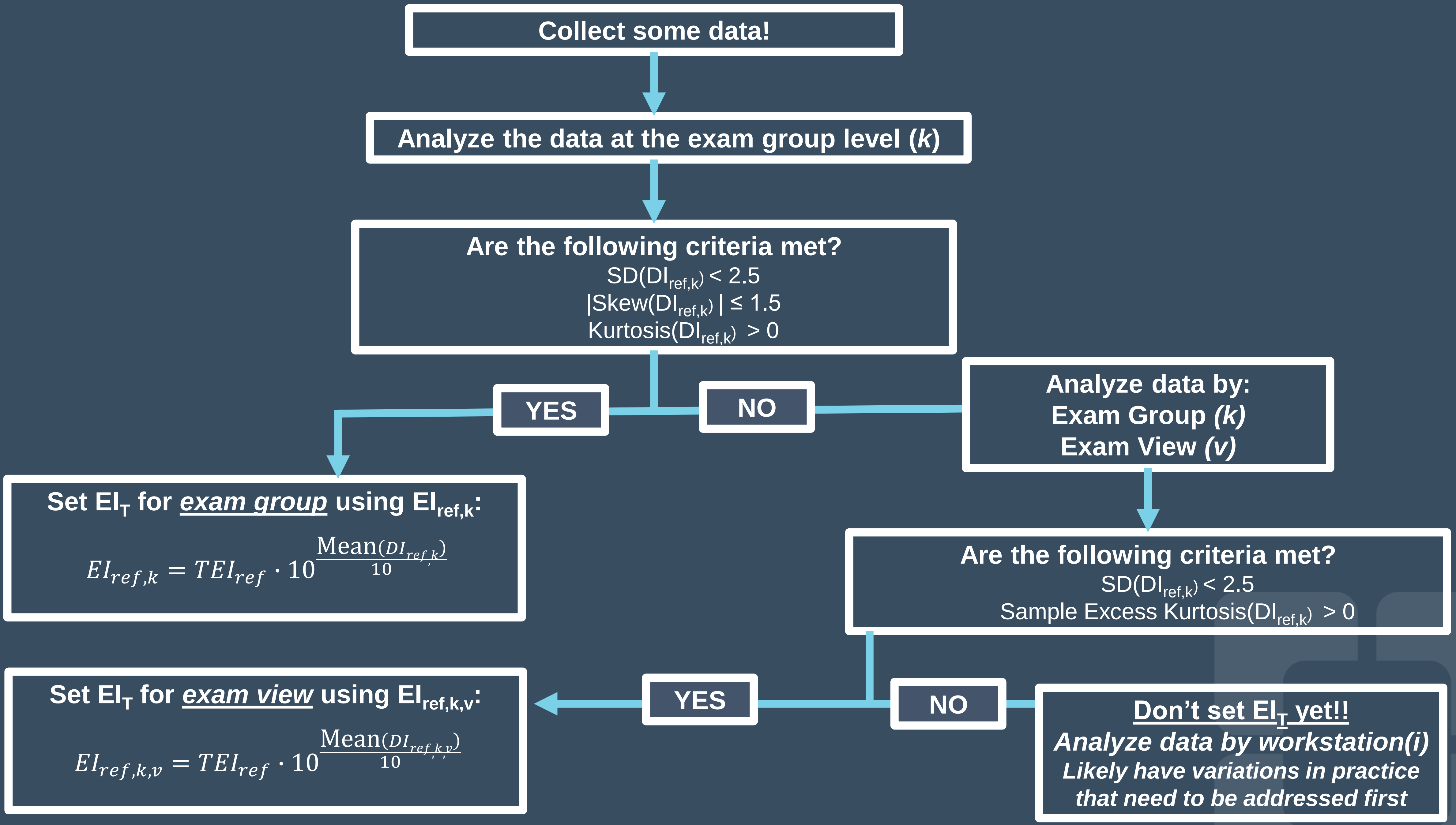
- Perform ongoing analysis of dose statistics and implement flag criteria to identify specific exams/views at individual sites for review using some combination of:
    - Mean(DI)
    - SD(DI)
    - Skew and Kurtosis?
- This requires a centralized (non-manual) method for collecting dose statistics…. (which we don’t have yet)

Summary

- Standard deviation, skew, and kurtosis of distribution in DI_{ref} can be used to systematically determine:
  - When EI_T values can be derived from the mean(DI_{ref}) for a given exam or view
  - When the state of practice is highly varied and further investigation may be needed before appropriate EI_T values can be set
- Exact criteria for these metrics may differ depending on practice and vendor

Cleveland Clinic

Every life deserves world class care.


Collect some data!
Analyze the data at the exam group level (*k*)
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
$|Skew(DI_{ref,k})| \leq 1.5$
$Kurtosis(DI_{ref,k}) > 0$
YES
NO
Analyze data by:
Exam Group (*k*)
Exam View (*v*)
Set EI_T for ***exam group*** using $EI_{ref,k}$:
$EI_{ref,k} = TEI_{ref} \cdot 10^{\frac{Mean(DI_{ref,k})}{10}}$
Are the following criteria met?
$SD(DI_{ref,k}) < 2.5$
Sample Excess $Kurtosis(DI_{ref,k}) > 0$
YES
NO
Set EI_T for ***exam view*** using $EI_{ref,k,v}$:
$EI_{ref,k,v} = TEI_{ref} \cdot 10^{\frac{Mean(DI_{ref,k,v})}{10}}$
Don't set EI_T yet!!
Analyze data by workstation(i)
Likely have variations in practice that need to be addressed first