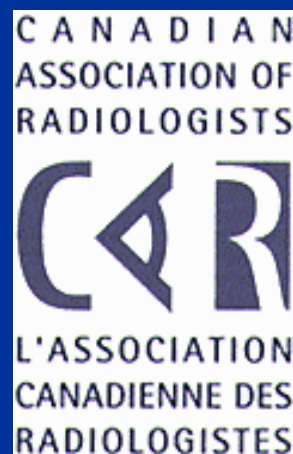


Lossy Compression as a Standard of Practice: A Pan-Canadian Study to Evaluate Compression Ratios for use in National Guidelines.

David A. Koff MD
Peter Bak PhD
Paul Brownrigg MBA
Alex Kiss PhD
Luigi Lepento MD, FRCPC
Tracy Michalak MSc
Harry Shulman MD, FRCPC
Andrew Volkening MSc



The CAR PACS Committee Position

- The Canadian Association of Radiologists PACS/Teleradiology committee has **accepted the principle of irreversible (“lossy”) compression** for use in primary diagnosis and clinical review, using DICOM JPEG or JPEG-2000 compression algorithms, at specific compression ratios set by image type.

The CAR PACS Committee Position

- The Canadian Association of Radiologists, with assistance from the Fraser Health Authority and Infoway, has decided to conduct a **clinical evaluation** to assess the most appropriate compression ratios in JPEG and JPEG 2000.
- **Guidelines** will be presented to the CAR steering committee and recommended for adoption based on the results of this evaluation study.

Methodology

Methodology

5 modalities (CR/DR, CT, US, MR, NM) and **7 radiological areas** (Angio, Body, Breast, Chest, MSK, Neuro, Pediatrics)

	CR/DR	CT	US	MR	NM
Angio		x		x	
Body	x	x	x	x	x
Breast	x		x	x	
Chest	x	x			
MSK	x	x	x	x	
Neuro		x		x	
Pediatrics	x	x	x	x	x

Methodology

- Images were compressed in JPEG and JPEG 2000 at 3 different ratios, close to acceptability, based on previous studies, below and beyond.

Modality	Low	Medium	High
CR/DR	20	25	30
CT	10	12	15
US	8	10	12
MR	16	20	24
NM	7	9	12
Angio	8	12	16

Methodology

Based on previous studies, our evaluation resulted from the association of 2 accepted methods:

- **Diagnostic accuracy evaluation with ROC analysis**
- **Image comparison with original-revealed forced choice (JND)**

ROC

- Images are a mixed of normal cases and identified pathologies (4 abnormal:1 normal)
- Images presented full screen compressed in JPEG and JPEG 2000 at 1 of the 3 different ratios or in original size.

ROC

Using normal images is important for two reasons:

- It allows to examine the possibility of artifacts that simulate abnormalities in a normal image.
- It addresses the possibility of bias that could occur if readers know that each image contains some abnormality.

ROC

- The entire set of images was randomized. To prevent potential bias due to recognizing a given image, readers were not shown the same image twice under different compression levels or algorithms.
- A restricted number of pathologies were listed in a drop-menu from which the reader had to chose.

ROC

- Reviewer had to specify in which sector of the image s/he saw the pathology and had to give a confidence rating on a scale from 1 to 5 (1=definite absence of lesion and 5= definite presence).

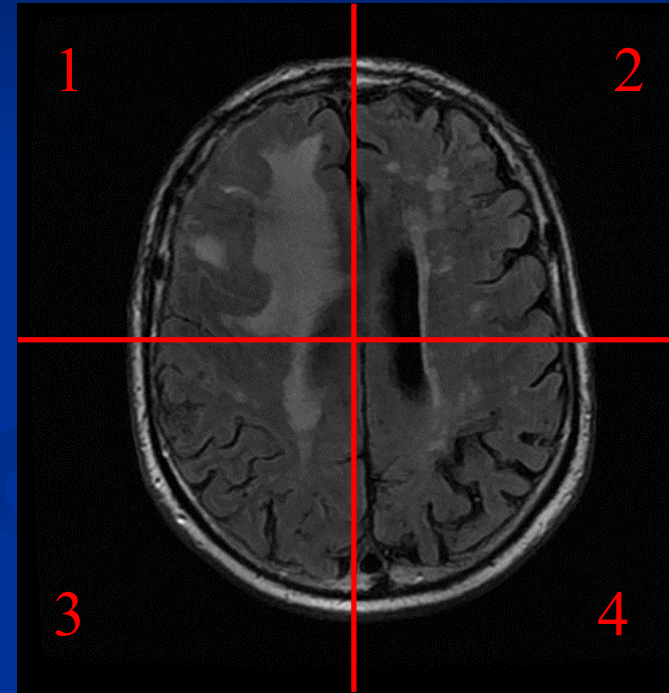


Image comparison with original-revealed forced choice (JND)

- Each compressed image was paired with the original
- Observer was asked to rate the degradation in image quality, which could impair interpretation, on a scale of 1 to 6.

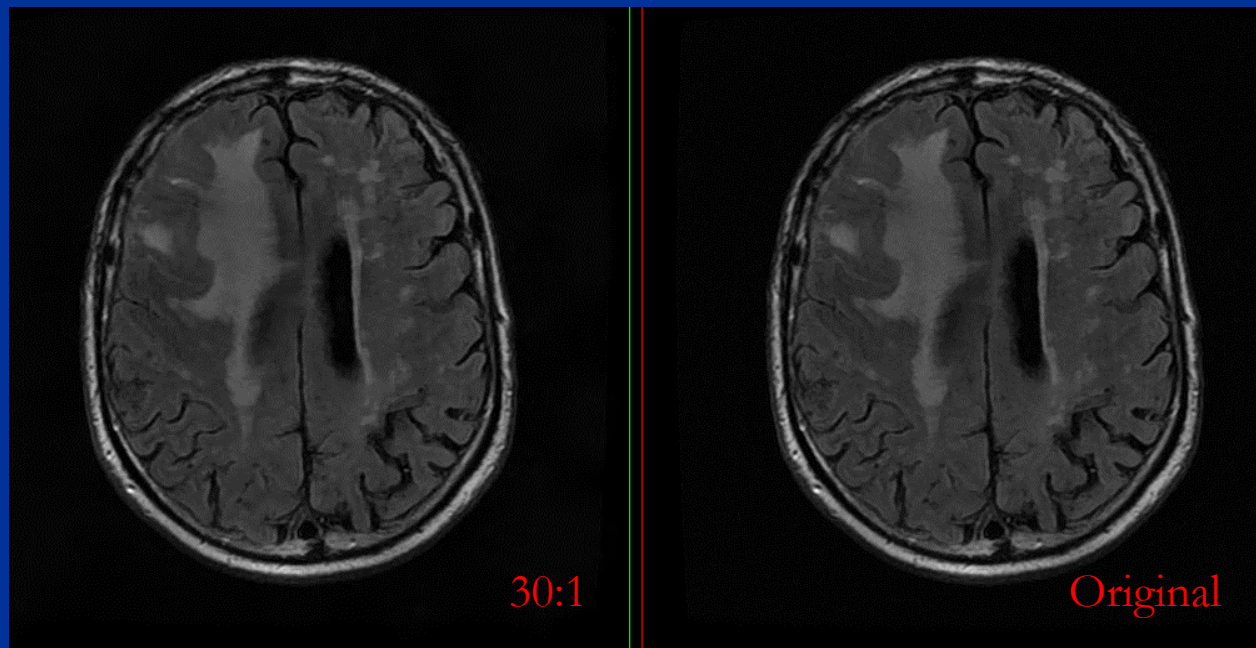


Image comparison with original-revealed forced choice (JND)

6	None	No Detectable Difference
5	Just noticeable	No Loss of Diagnostic Information
4	Conspicuous	Bordering on Loss of Information
3	Intermediate	Subtle Abnormalities Could be overlooked
2	Significant	Important Diagnostic Information Could be Lost, Degradation Impairs Interpretation
1	Unacceptable	Inadequate for Diagnosis; Definite Loss of Diagnostic Information

Methodology

- 3 readers per session, 23 sessions, more than 100 readers in total from all across Canada.
- Had to read the images on the DICOM compliant, calibrated workstation they use in their daily activity.
- The workstation had to be connected to the Internet ideally.
- Appropriate reading environment with correct ambient light.

Methodology

- Each reader received a CD with 70 images or image stack of no more than 20 images for CT scan.
- The session could be interrupted at any time and resumed automatically where stopped.
- The answers were filled on-line and directly transferred to our server.
- If user could not connect his workstation to the Internet, an alternate paper-based solution was provided.

Technical developments

Technical developments

- An industry recognized compression engine from Pegasus Inc. (Tampa, FL): PICTools with JPEG 2000 and Lossy JPEG.
- DICOM communication: MergeCOM-3 from Merge-Cedara

Technical developments

- A standalone administrator application allowing:
 - Database of anonymized cases
 - Database of participating radiologists
 - Compression engine
 - Creation and compilation of worklists
 - CD/DVD engraving

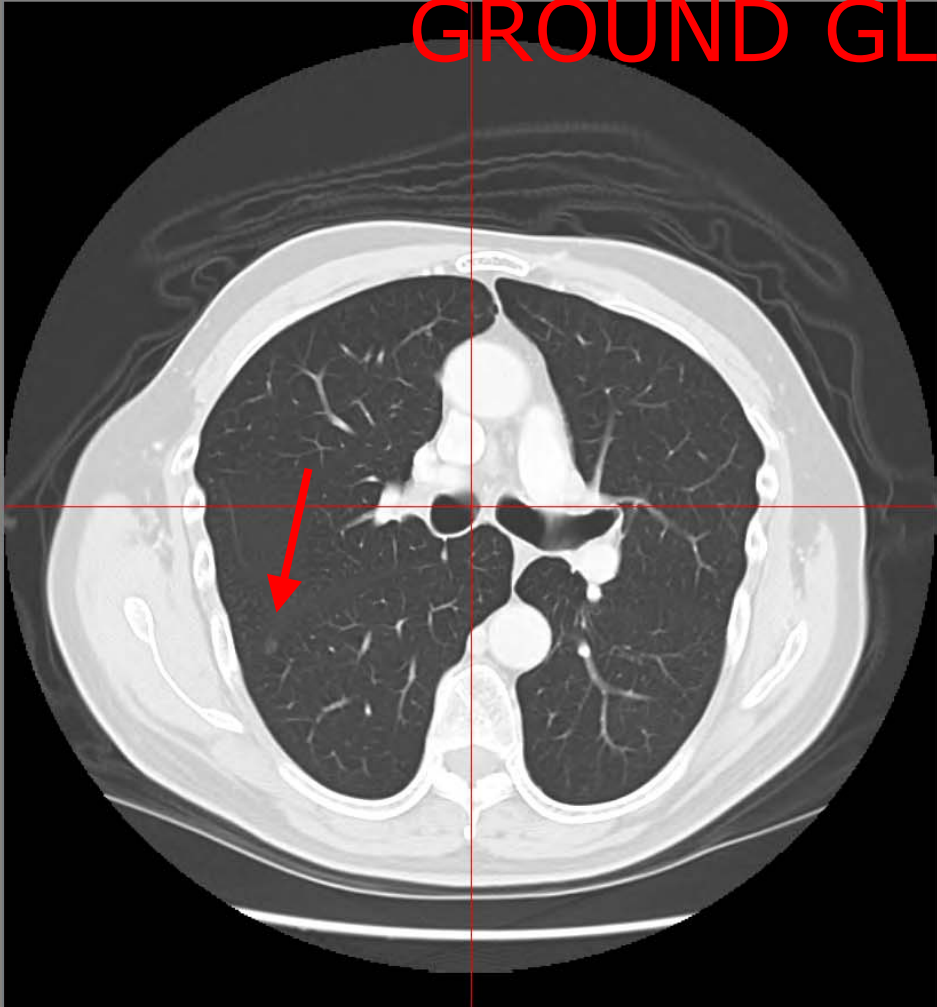
Technical developments

- A specially designed viewing software to display images to review at the different levels of compression then side by side paired with the original when revealed.
- Limited processing functions were provided:
 - Zoom
 - Pan
 - Window-leveling
 - Reset

ROC

CompressViewer Study 5 of 20

GROUND GLASS OPACITY



Specify Abnormality:

What Region?:

Confidence level?:

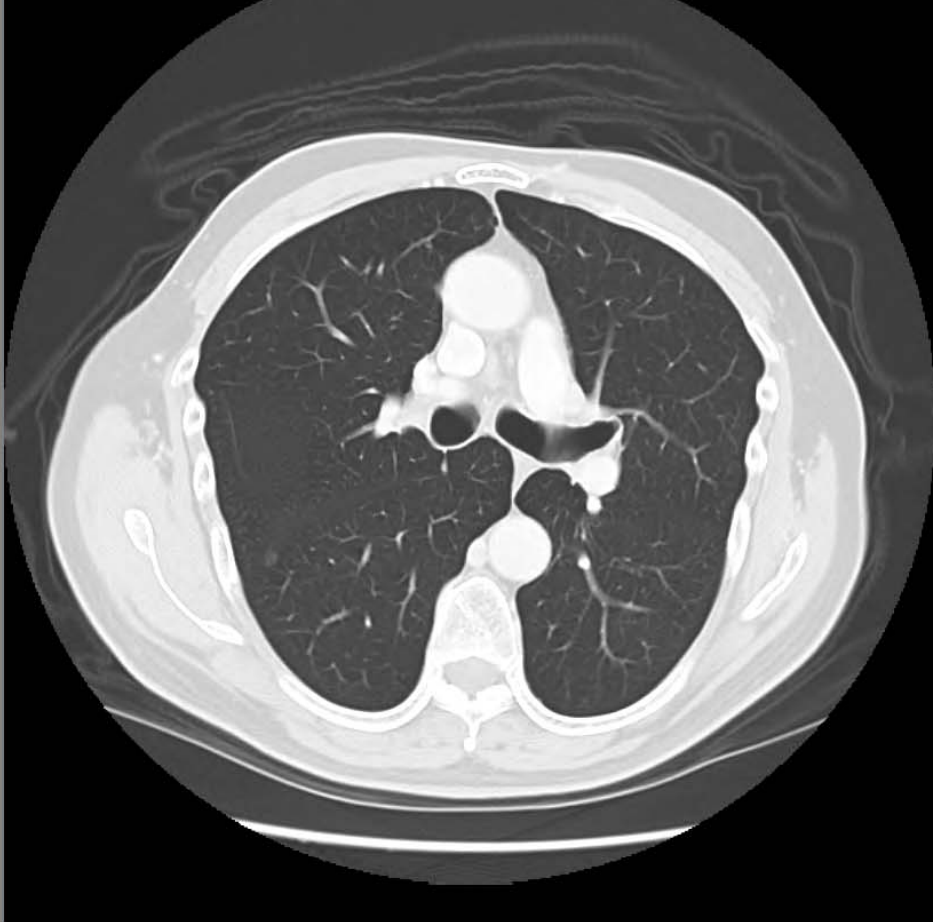
Toggle Grid Image 6

JND

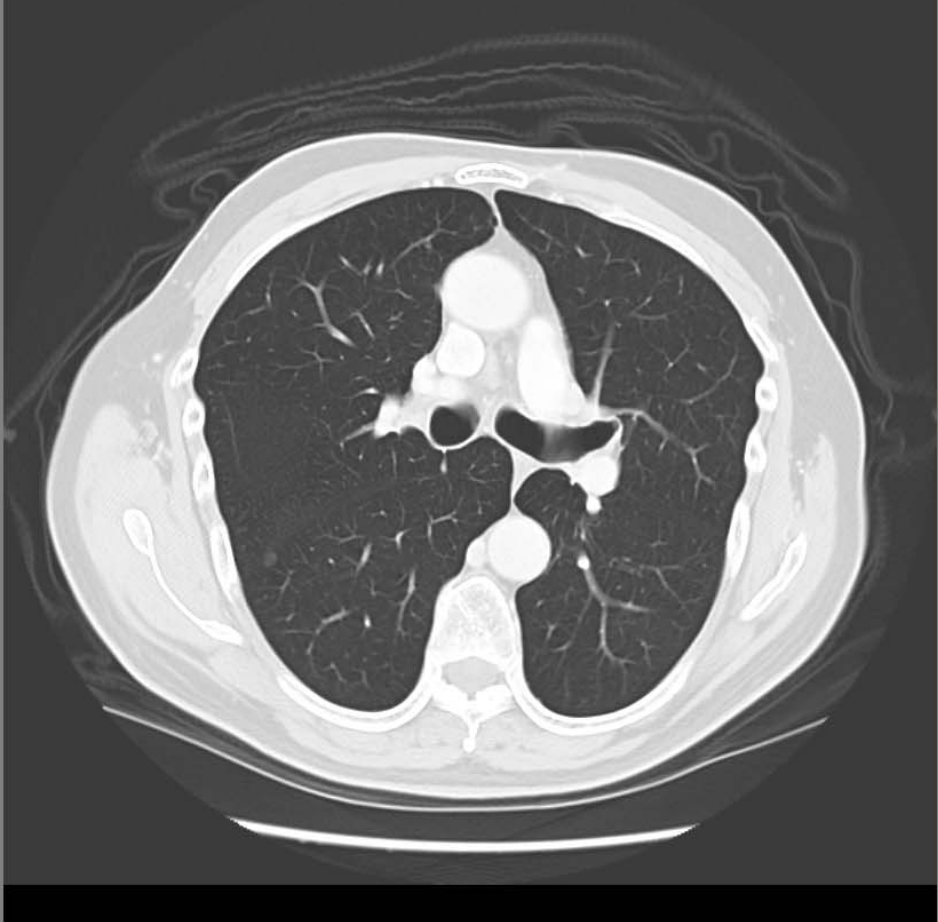
CompressViewer



JPEG 2000 15:1



ORIGINAL



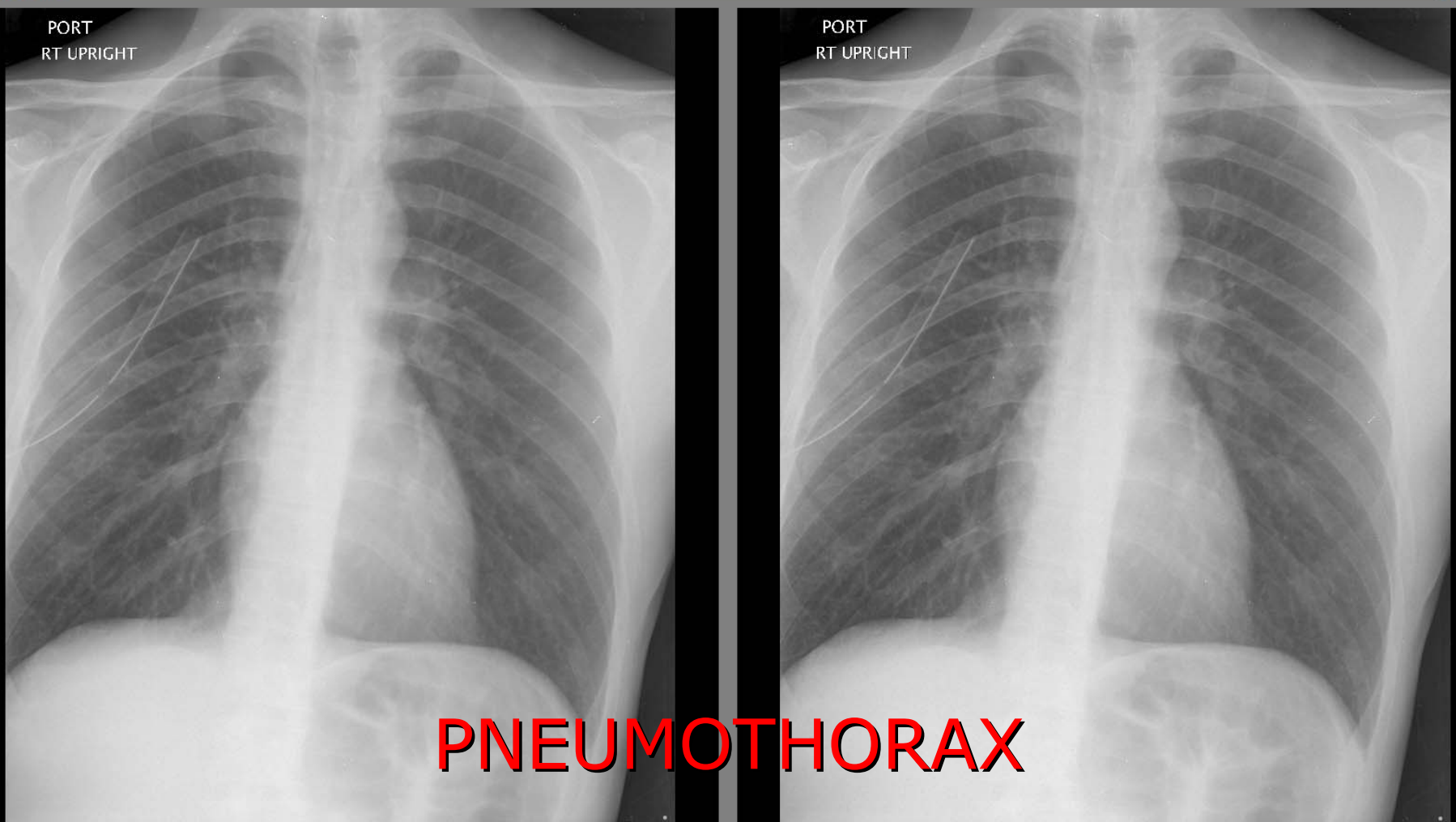
Zoom Pan Window/level Reset Toggle Grid Image 6

Difference assesment -- Assesment --

COMPARISON SIDE BY SIDE

CompressViewer

PORT
RT UPRIGHT



PORT
RT UPRIGHT

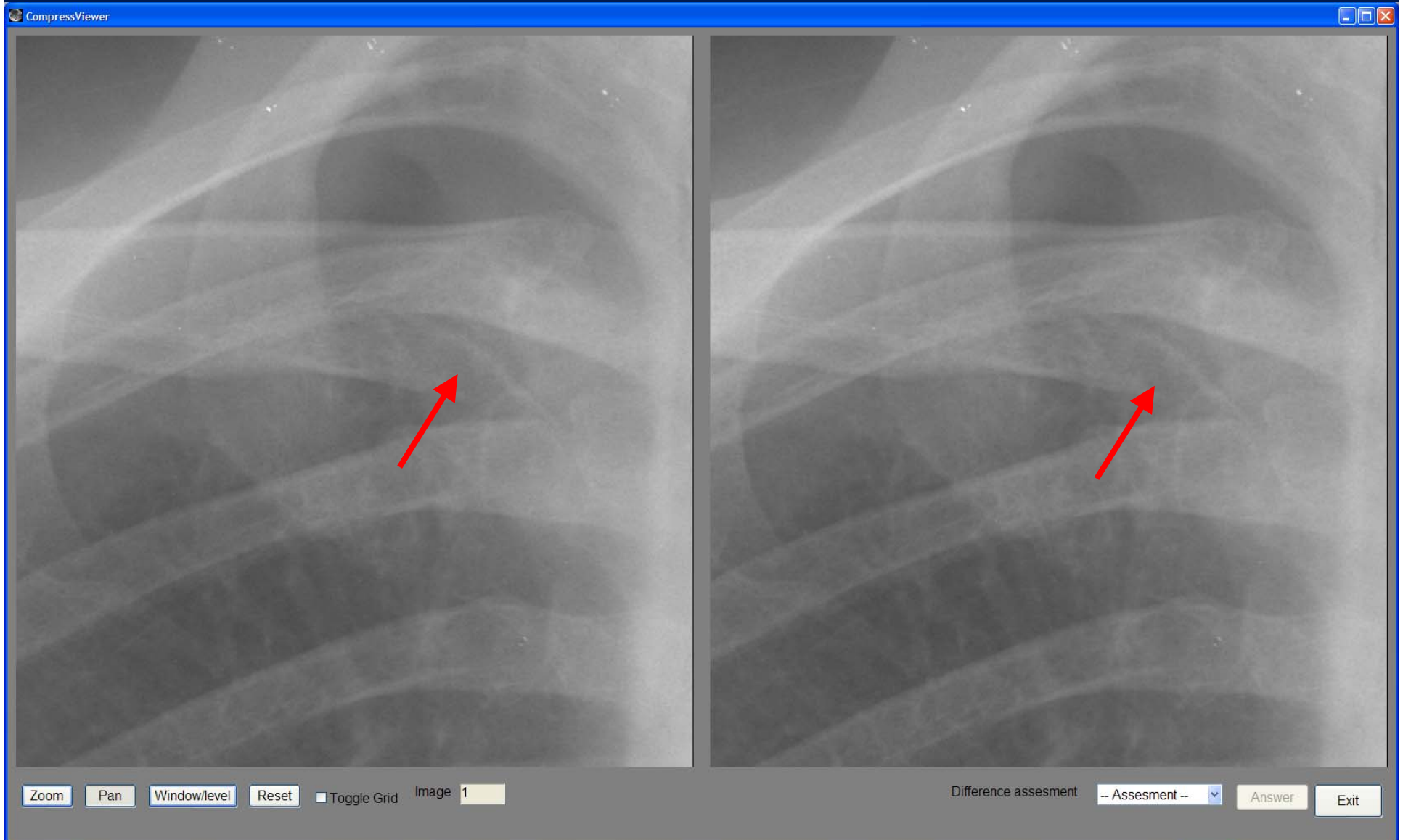
PNEUMOTHORAX

Zoom Pan Window/level Reset Toggle Grid Image 1

Difference assesment -- Assesment -- Answer Exit

JPEG 25:1

ORIGINAL



Results

Results

On 23 sessions, only 2 have not been completed yet:
Breast CR and Pediatrics CT , and will be shortly.

	CR/DR	CT	US	MR	NM
Angio		X		X	
Body	X	X	X	X	X
Breast	X		X	X	
Chest	X	X			
MSK	X	X	X	X	
Neuro		X		X	
Pediatrics	X	X	X	X	X

Results

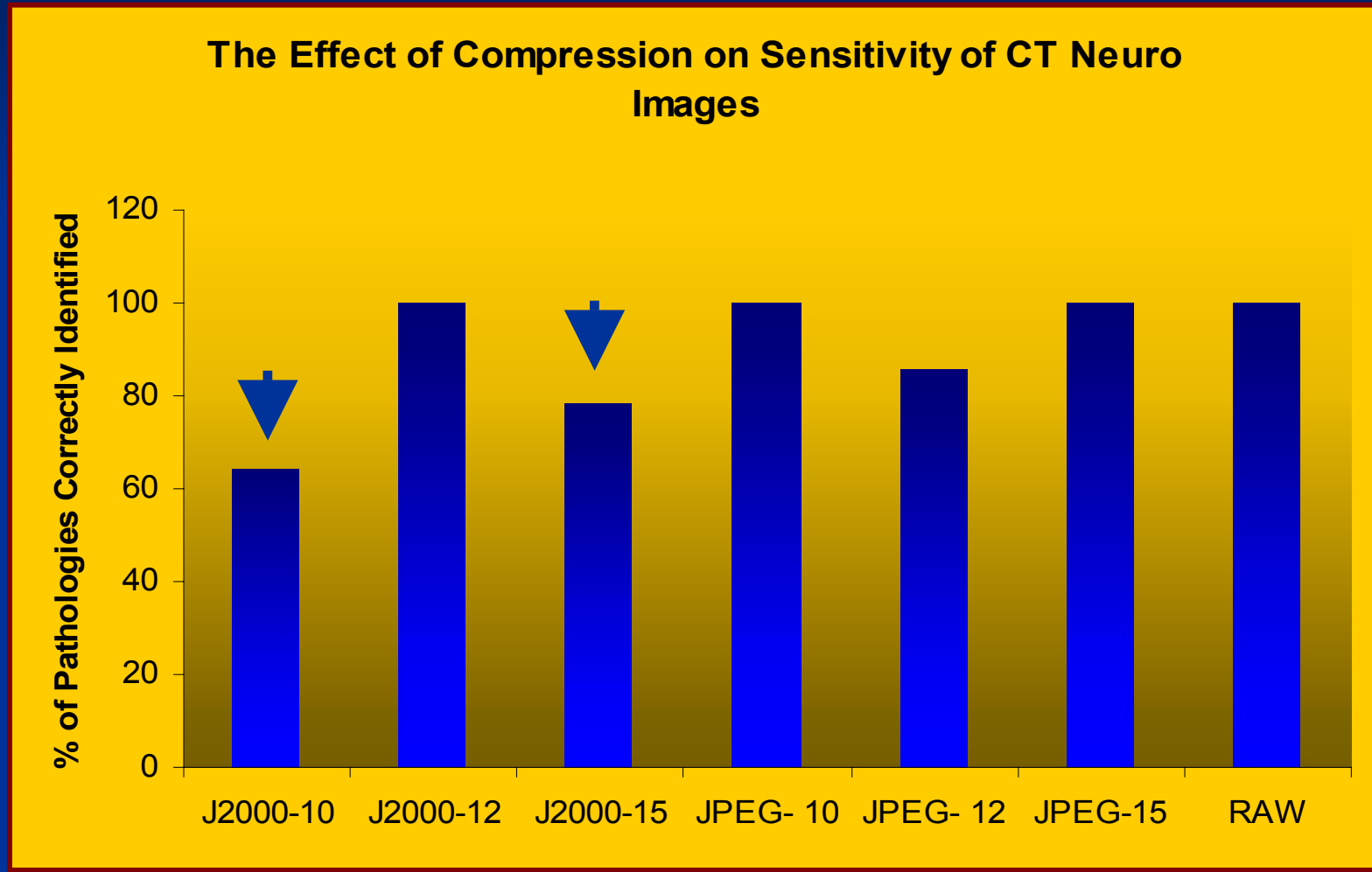
For 18 anatomical regions/modalities, there was no difference noted, but discrepancies were noted in 3 occurrences.

	CR/DR	CT	US	MR	NM
Angio		X		X	
Body	X	X	X	X	X
Breast	X		X	X	
Chest	X	X			
MSK	X	X	X	X	
Neuro		X		X	
Pediatrics	X	X	X	X	X

Results - ROC

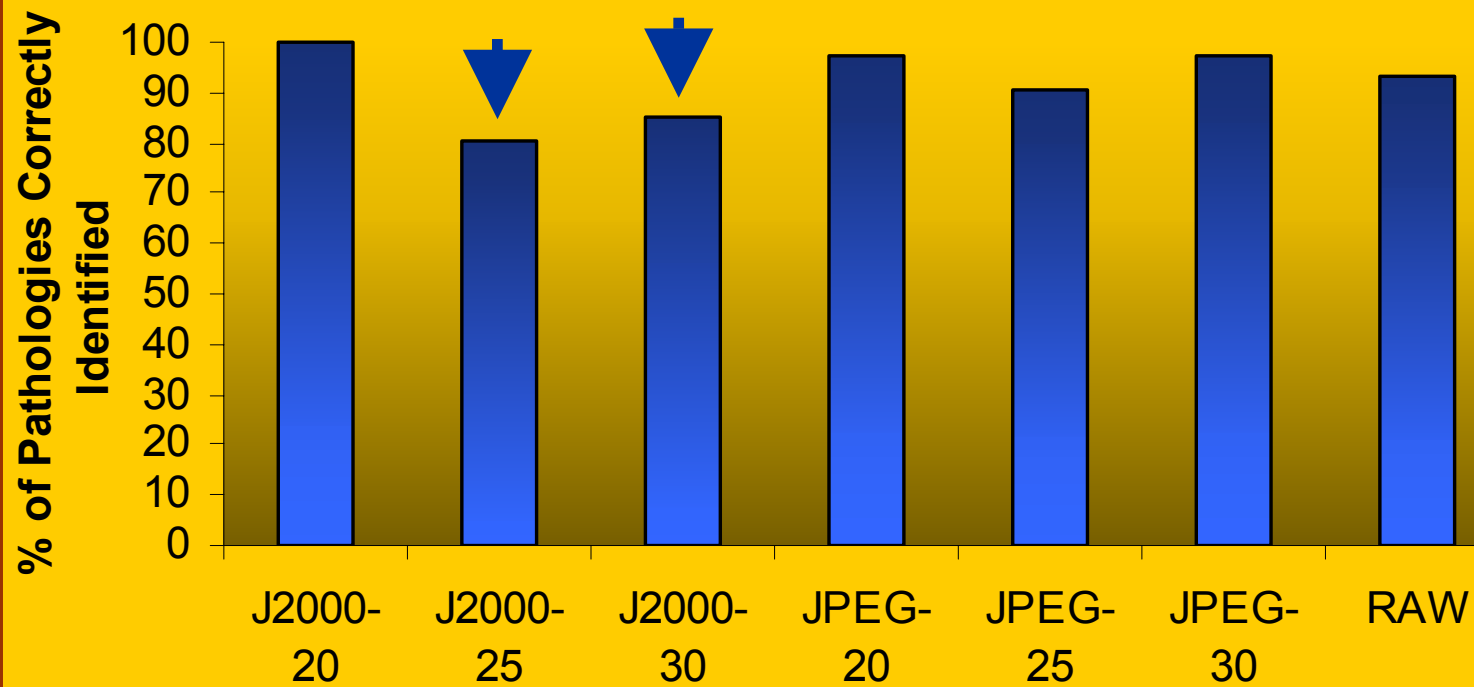
- For CT Neuro, statistical differences were found on sensitivity for the type of compression, with JPEG found to be more sensitive on average (0.95 versus 0.81).
- For CR MSK, statistical differences were found on sensitivity for the level of compression with JPEG found to be more sensitive than JPEG 2000 at 25:1 (0.91 vs. 0.80) and at 30:1 (0.97 vs. 0.85).
- No statistical difference were found on the other measures.

Results - ROC



Results - ROC

The Effect of Compression on Sensitivity of CR
MSK Images

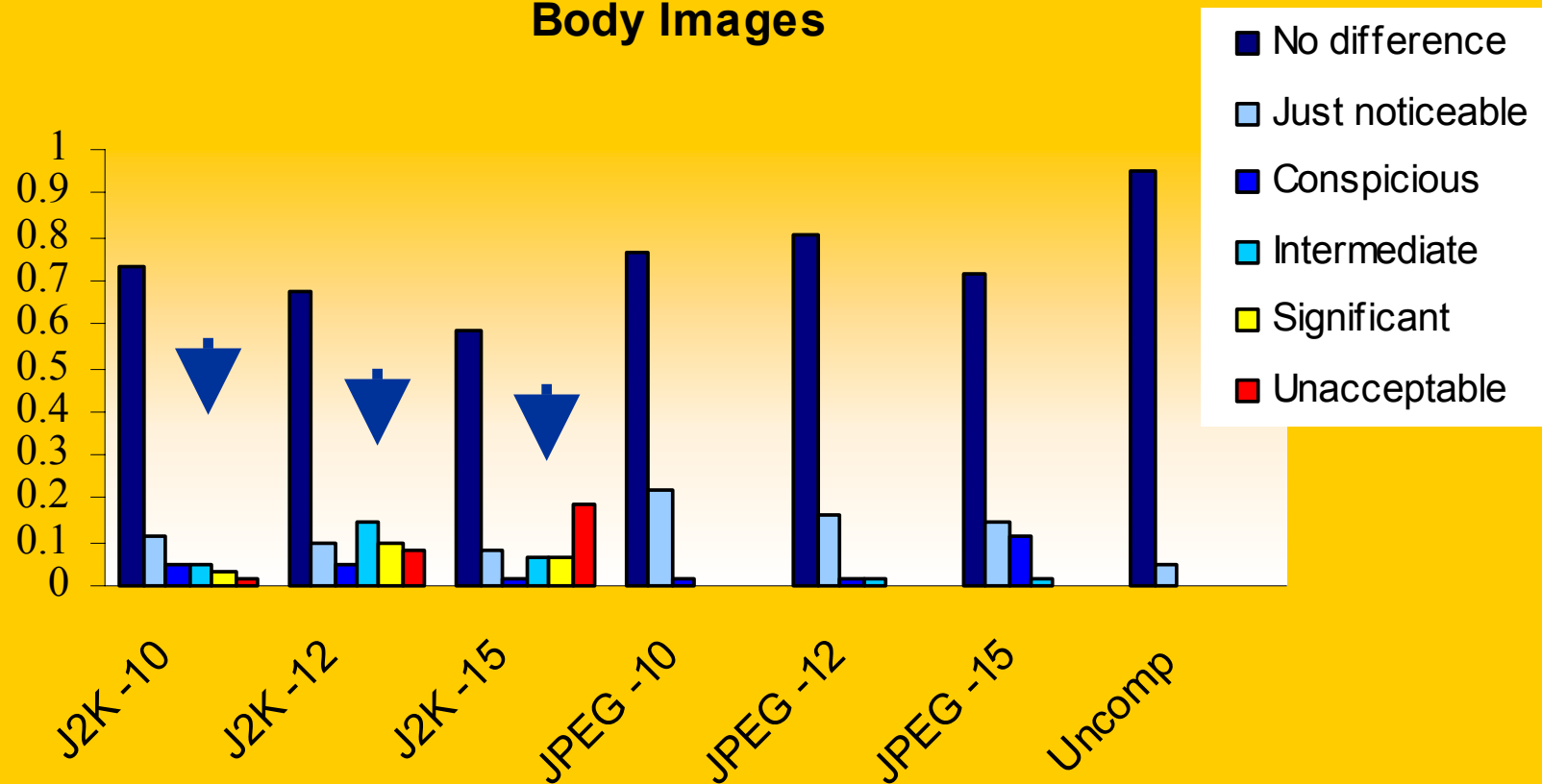


Results - JND

- For CT Body, a significant difference was found between type of compression with a greater proportion of readers choosing categories 1, 2 and 3 (unacceptable to intermediate) for JPEG 2000.
- For CT Neuro, a significant difference was found between type of compression with a greater proportion of readers choosing categories 1, 2 and 3 (unacceptable to intermediate) for JPEG 2000.
- No statistical difference were found on the other measures.

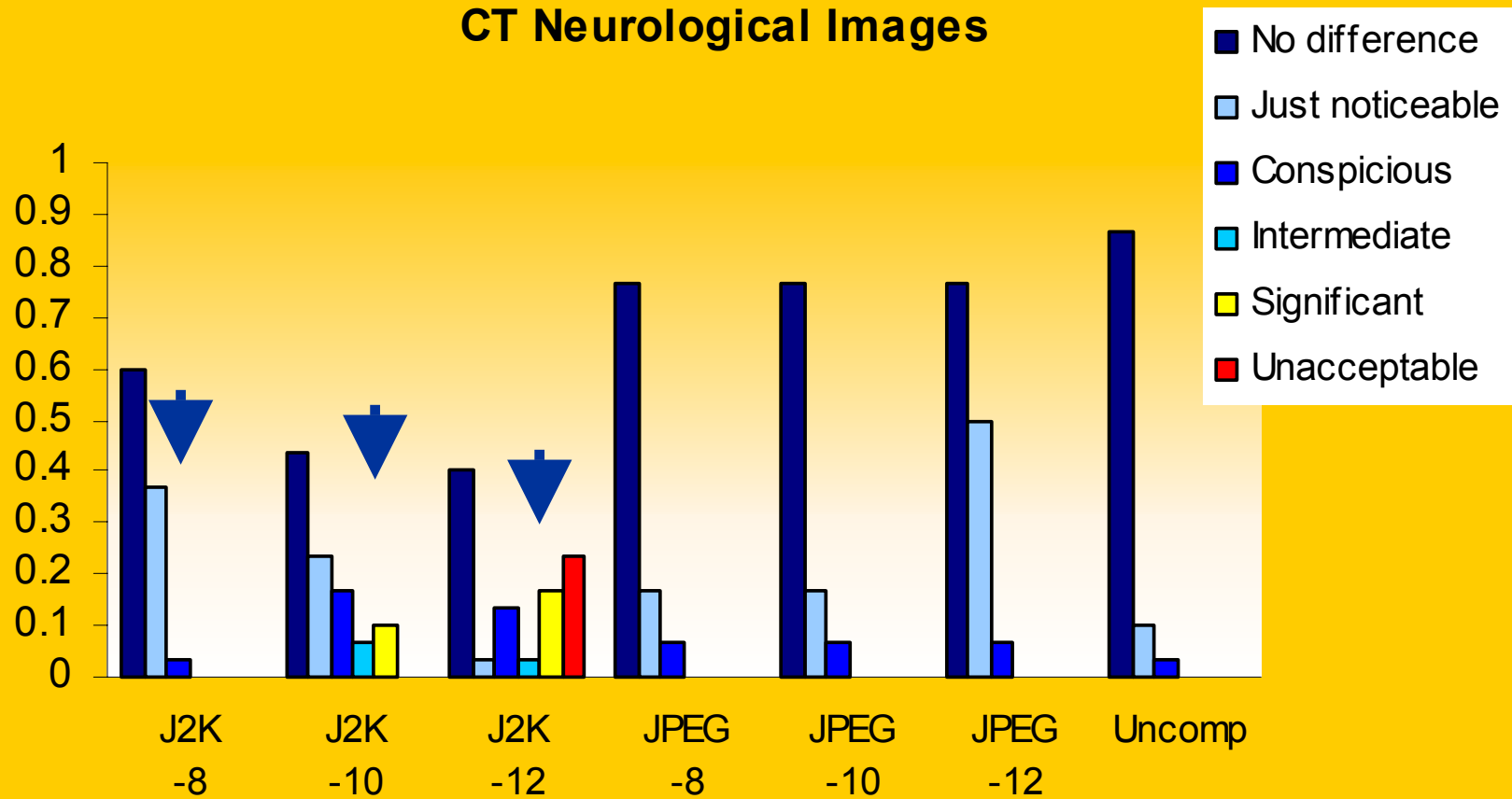
Results - JND

The Effect of Compression on Subjective Assessment of CT Body Images



Results - JND

The Effect of Compression on Subjective Assessment of CT Neurological Images



Conclusion

- **Lossy compression can be used at the lowest levels of compression tested, as there is no significant loss of diagnostic information at those levels.**
- **No difference between Lossy JPEG and JPEG 2000 at the lowest levels of compression, but JPEG performs better than JPEG 2000 on high frequency low energy CT images.**

Recommended values

	CR/DR	CT	US	MR	NM	MG
Angio		10-15		16-24		
Body	20-30	JPEG 10-15 J2K 10	8-12	16-24	9-11	
Breast			8-12	16-24		15-25
Chest	20-30	10-15				
MSK	JPEG 20-30 J2K 20	10-15	8-12	16-24		
Neuro		JPEG 8-12 J2K 8		16-24		
Ped	20-30	10-15	8-12	16-24	9-11	

Recommended values

	CR/DR	CT	US	MR	NM	MG
Angio		10-15		16-24		
Body	20-30	JPEG 10-15 J2K 10	8-12	16-24	9-11	
Breast			8-12	16-24		15-25
Chest	20-30	10-15				
MSK	JPEG 20-30 J2K 20	10-15	8-12	16-24		
Neuro		JPEG 8-12 J2K 8		16-24		
Ped	20-30	10-15	8-12	16-24	9-11	

20

8-10

16

15