

Resolution, SNR, Signal Averaging and Scan Time in MRI for Metastatic Lesion in Spine: A Case Report in a 74 Years Old Patient

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Case Report

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Abstract

Background: MRI image quality is compromise between resolution, scan time, Signal Averaging (NSA/NEX.), SNR and Integrated parallel acquisition technique (SENSE). Any compromise in any of these parameters can lead to poor quality images that can lead to misdiagnosis. The higher the image resolution, the better the small pathologies can be diagnosed, thus it is the goal of imaging a good quality scan by using a standardized protocols.

Methods: The study was conducted in Department of Medical Imaging, Medcare International Hospital, Gujranwala, Pakistan, Gujranwala Institute of Nuclear Medicine & Radiotherapy (GINUM), Gujranwala, Pakistan.

Case Presentation: We present a case of 74 year old man with severe lower back pain. His initial MRI did not reveal any significant pathology; however a repeat MRI revealed metastatic involvement of the lumbar vertebrae.

Conclusion: Standardized MRI protocols have been developed after much study to optimize all the parameters. Any modification in the protocols to reduce image time is therefore hazardous. It is therefore imperative that they be followed in order to avoid generating suboptimal images.

Keywords: MRI; Signal-to-Noise Ratio; SNR; Resolution; Metastasis; NSA/NEX; IPAT; SENSE Case Report

Abbreviations: MRI: Magnetic Resonance Imaging; STIR: Short-TI Inversion Recovery; SNR: Signal to Noise Ratio; CME: Continuing Medical Education; T1W: T1 Weighted Images; T2W: T2 Weighted Images; NSA: Signal Averaging; SENSE: Sensitivity Encoding; IPAT: Integrated Parallel Acquisition Technique.

Introduction

Resolution is the ability of human eyes to distinguish one structure from other. In MRI the resolution is

determined by the number of voxels in a specified FOV. The higher the image resolution, the better the small pathologies can be diagnosed. Resolution is directly proportional to the number of voxels. Voxel size can be calculated by dividing the FOV by the matrix size (e.g. FOV 320, Matrix 320x320, voxel size is 320/320=1mm). There are two resolution parameters used in MRI for the production of a 2D image i.e. basic resolution & phase resolution [1,2].

Basic Resolution

Basic resolution is the number of voxels in redout direction. Basic resolution determines the size of the image matrix. Basic resolution is inversely proportional to the size of the voxel [2].

SNR & Basic Resolution

SNR is inversely proportional to the basic resolution. In other words SNR is directly proportional to the voxel size, increasing the base resolution will reduce the voxel size therefore the SNR of the image [3,4] will be reduced (Figure 1).

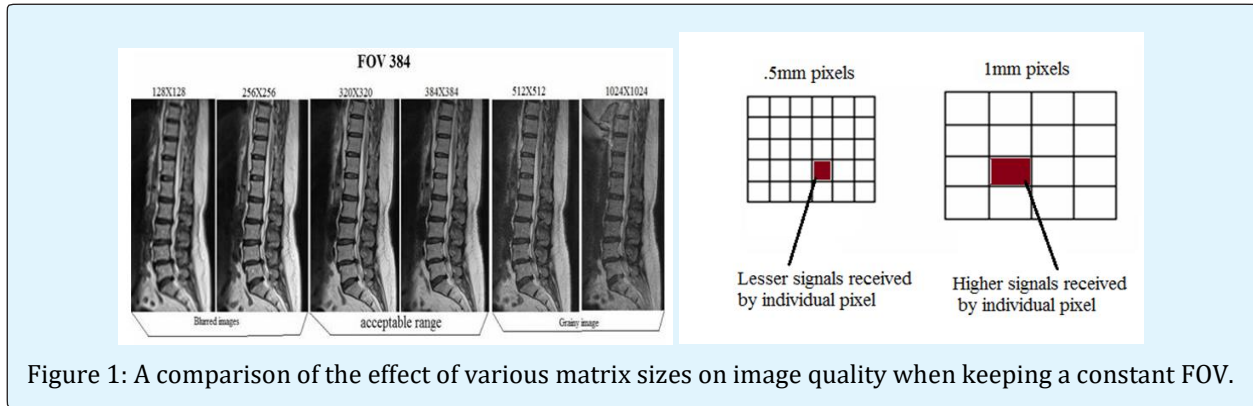


Figure 1: A comparison of the effect of various matrix sizes on image quality when keeping a constant FOV.

If we compare a 256x256 and 128x128 matrix formats, the voxel size of 128 (2x2mm) matrix is four times larger than the 256(1x1mm) matrix but there are only half phase encoding steps. Therefore the SNR is calculated by $4\sqrt{2} = 2.82$ (Table 1).

Matrix	Relative SNR
128x128	2.82 ($1 \times 2.8 = 2.82$)
256x256	1
512x512	0.35 ($1/2.82 = 0.35$)

Table 1: Relationship between Matrix size and SNR

Increasing the basic resolution will increase the image quality. Increasing the resolution more than the acceptable range will produce noisy or grainy image due to low SNR and reducing the basic resolution more than the acceptable range will produce a blurry image due to high SNR [4]. Increasing the basic resolution will result in a prolonged scan time. Ways to improve a low resolution / blurred image. Improvement in scan time leads to a higher resolution and sharper images (Figure 2).

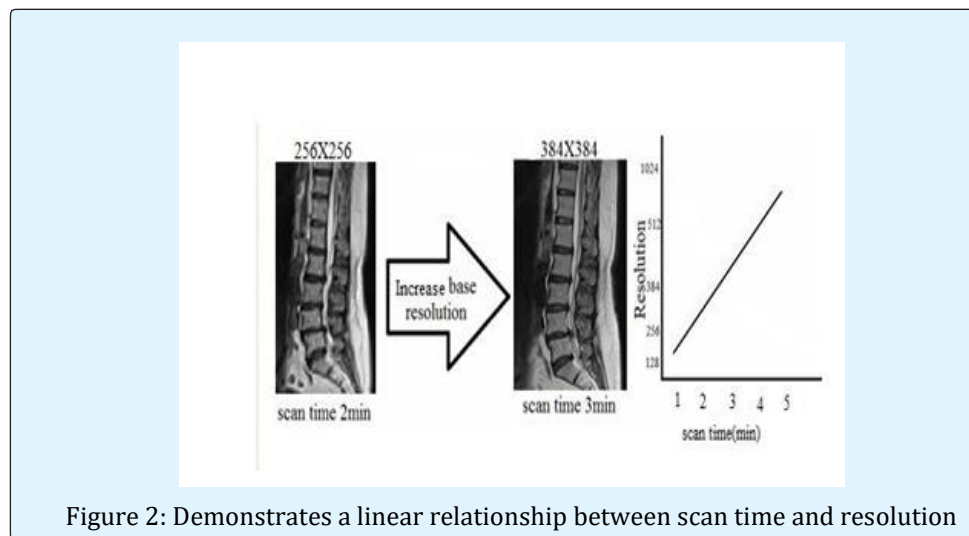
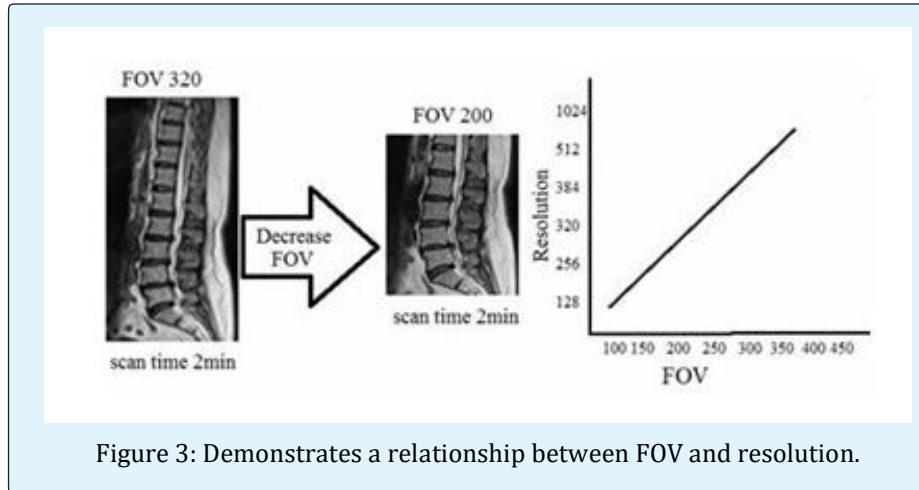


Figure 2: Demonstrates a linear relationship between scan time and resolution

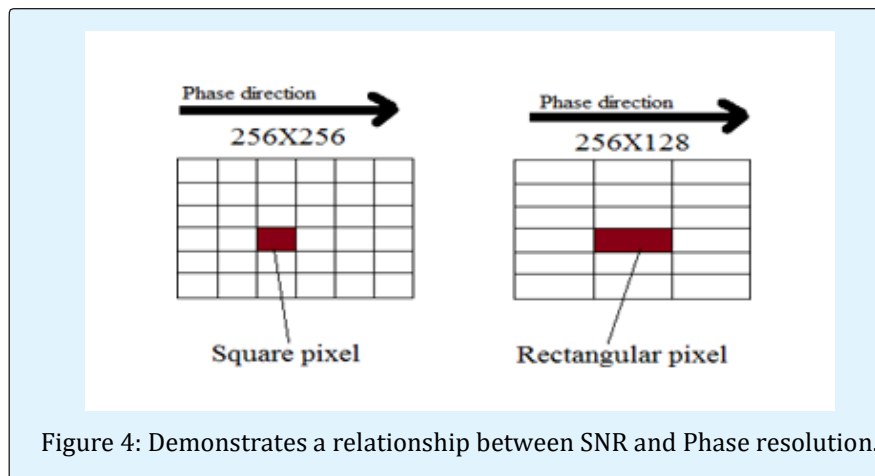
Decreasing FOV reduces the voxel size and SNR therefore the image will become sharper (Figure 3).



SNR & Phase Resolution

Decreasing the phase resolution will reduce the image quality and scan time. Reducing the phase resolution will

increase the voxel size therefore the SNR will increase considerably (Figures 4 & 5, Table 2).



FOV readout	FOV phase	Phase resolution	Matrix Size	Pixel (mm)
256 mm	100%	100%	256x256	1x1
256 mm	100%	75%	256x192	1x1.33
256 mm	100%	50%	256x128	1x2
256 mm	100%	25%	256x64	1x4

Table 2: Demonstrates a relationship between SNR and Phase resolution.

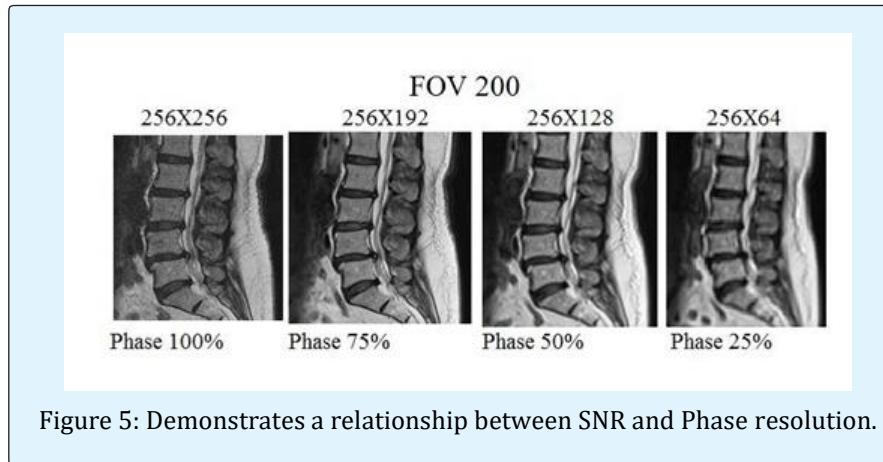


Figure 5: Demonstrates a relationship between SNR and Phase resolution.

Signal Averaging

A signal to noise improvement method that is accomplished by taking the average of several FID's made under similar conditions to suppress the effects of random variations or random artifacts. It is a common method to increase the SNR by averaging several measurements of the signal. The number of averages is also referred to as the number of excitations (NEX) or the number of acquisitions (NSA). Doubling the number of acquisitions will increase the SNR by the $\sqrt{2}$. The approximate amount of improvement in signal to noise (SNR) ratio is calculated as the square root of the number of excitations [5].

By using multiple averages, respiratory motion can be reduced in the same way that multiple averages increase the signal to noise ratio. NEX/NSA will increase SNR but will not affect contrast unless the tissues are being lost in noise (low CNR). Scan time scales directly with NEX/NSA and SNR as the square root of NEX/NSA. The use of phase array coils allows the number of signal averages to be decreased with their superior SNR and resolution, thereby decreasing.

Sense (IPAT)

With SENSE, two or more coil elements acquire imaging data simultaneously, enabling a scan time reduction by a factor of up to the number of coil elements used. The major negative point of parallel imaging techniques is that they diminish SNR in proportion to the numbers of reduction factors [4]. R is the factor by which the number of k- space samples is reduced. In standard Fourier imaging reducing the sampling density results in the reduction of the FOV, causing aliasing. As long as the actual phase percentage is close to the requested phase percentage, the resulting image will be fine. The difference can increase when higher TFE-factors are used, and in that case you might need to tune the sequence (change number of phases, spatial resolution and/or SENSE factor) to avoid that the actual phase percentage is much lower than the requested phase percentage: this could lead to increased temporal blurring.

Parameters Benefits and Trade-offs

The relationships between MR imaging parameters are complex. The table shows the effects of increasing or enabling a parameter (set to "Yes") on scan time, resolution, signal-to-noise ratio (SNR) and artifact level for some parameters (Table 3).

↓ lower, ↑ higher, = unchanged, • more information available in following Table				
Parameter	Scan time	Resolution	SNR	Artifacts
NSA	↑	=	↑	↓
REST	↑	=	=	↓
Voxel Size	↓	↓	↑	↑/↓
FOV (In combination with fixed matrix size)*	=	↓	↑	=
FOV (In combination with fixed voxel size)*	↑	=	↑	=
Rectangular FOV (%)	↑	=	↑	=

Parameter	Scan time	Resolution	SNR	Artifacts
Scan Percentage (%)	↑	↑	↓	=
Slice thickness	=	↓	↑	=
Scan Matrix	↑	↑	↓	=
Halfscan	↓	=	↓	↑
SMART	=	=	=	↓
Water Fat Shift	=	=	↑	↑
3D Slices	↑	=	↑	=
SE Flip Angle	=	=	↓	=
Flowcomp FFE, TSE	=	=	↓	↓
Flowcomp SE	=	=	=	↓
Partial Echo	=	=	↑/↓	↑/↓
SPIR/ ProSet	↑	=	=	↓
SENSE	↓	=	↓	=

The effect of parameter FOV can differ depending on the way of working: you can either adjust the **Matrix size** or the **voxel size**. The table illustrates the effects.

Way of working	FOV	Scan matrix	Pixel size	TE	TR	Scan time	SNR
Matrix size	↓	=	↓	↑ 1)	↑ 2)	↑	↓ 3)
Voxel size	↓	↓	=	=	=	↓	↓ 4)

Footnotes: 1) This is valid in case of TE= shortest.

For TE= user defined, this could lead to a conflict.

2) This is valid in case of TR= Shortest.

3) This is caused by smaller voxels.

4) This is caused by the reduction of scan time.

Table 3: Parameters benefits and trade-offs.

Instrumentation

MRI Systems

- Achieva (Philips) 1.5 T
- Magnetom-C (SIEMENS) 0.35T

Objective

The study is designed with following objectives:

- To detect the malignant lesions in spine by using standard protocols to obtain good quality images?
- How system optimization can influence the delectability, sensitivity and reliability of an imaging system of MRI?

Methods

The study was conducted in Department of Medical Imaging, Medcare International Hospital, Gujranwala, Pakistan, Gujranwala Institute of Nuclear Medicine & Radiotherapy (GINUM), Gujranwala, Pakistan.

Case Presentation

We present the case of a 74-year-old male with a history of severe lower back pain, bony aches, vomiting and abdominal pain. He was referred for an MRI spine

from a local hospital to evaluate a suspicious lytic lesion seen on x-ray. Two independent observers observed the both studies separately and gave their comments regarding the MRI studies. A first or previous MRI spine done two weeks earlier (using an Achieva Philips 1.5 Tesla system) had failed to characterize the lesion adequately by the first observer, simply showing intervertebral disc bulges (Figures 6 & 7).



Figure 6: T1 weighted sagittal images performed with the 1.5 Tesla Achieva (Philips) machines, which showing only disc bulges and single lesion at L2V, but not clear.

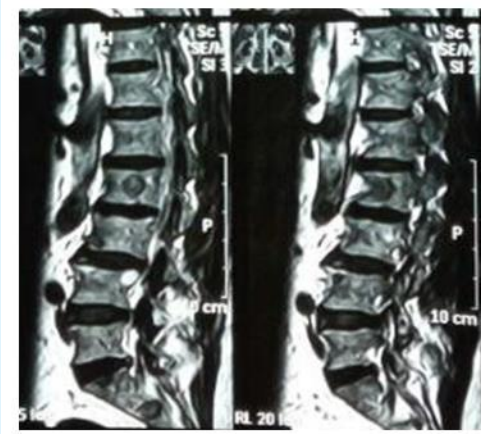


Figure 7: T2 weighted sagittal images performed with the 1.5 Tesla machine which showing only disc bulges and single lesion at L2V, but not clear.

A repeat MRI spine was performed at our institution using a 0.35 Tesla (Magnetom-C (SIEMENS) machine was using standardized protocol. The second scan revealed by second observer metastatic lesions in multiple dorso-lumbar vertebrae (Figures 8-12). Subsequently the earlier MRI was reviewed which also seemed to have similar changes but far less clear. The same was communicated to the referring physician who ordered a CT chest, abdomen & pelvis including biphasic to diagnose the site of primary lesion, which turned out to be cancer of head pancreas. Bony metastatic lesions were subsequently confirmed in bone scan performed at a local nuclear medicine facility by author BI.



Figure 8: T1 weighted sagittal images performed with 0.35 Tesla Magnetom-C (SIEMENS) machine which showing metastatic lesion at multiple levels of lumbosacral spine.

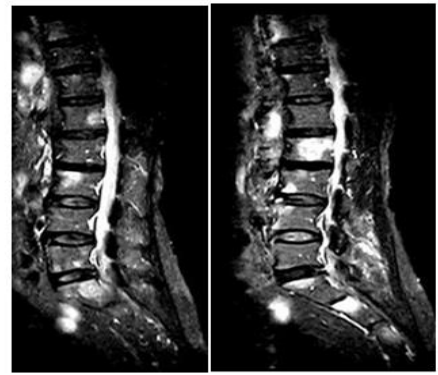


Figure 9: (T2 weighted and STIR Sagittal images performed with the 0.35 Tesla Magnetom-C (SIEMENS) MRI machine which showing hyper intense signals are metastatic lesions at multiple levels of vertebrae of lumbosacral spine.



Figure 10: T1 weighted sagittal images of dorsal spine performed with the 0.35 Tesla Magnetom-C (SIEMENS) machine. Which showing metastatic lesion at multiple levels of dorsal spine.



Figure 11: T2 weighted (Left) & T2 STIR weighted sagittal images of dorsal spine performed with the 0.35 Tesla Magnetom-C (SIEMENS) machine, which showing metastatic lesion at multiple levels of dorsal spine.

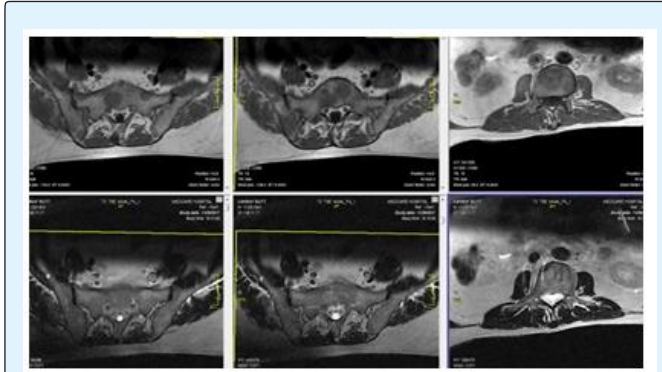


Figure 12: T1weighted (upper row) and T2 weighted (lower row) axial images of spine performed with the the 0.35 Tesla Magnetom-C (SIEMENS) machine, which showing metastatic lesion.

Both the MRI studies were technically analyzed by author WZ to discover the cause of missing metastatic lesions in the first MRI scan. It was observed that the image quality was suboptimal due to a compromise to minimize resolution, SNR, signal averages (NSA, NEX) and also applying SENSE technique to shorten the scan time, due to which there were blurry and poor quality images were acquired and information were lost which lead to misdiagnosis (Tables 5 & 6).

Following were the parameters of T1w sequence used of both MRI modalities

Sr. No	MRI Systems	Tesla	TR	TE	Scan Time	NSA/NEX (Avg)	Matrix (Base Resolution)	Phase Resolution	Filter	RFOV	Phase FOV	VOXEL Size	Slice Thickness	SENSE	COIL
1	Achieva (Philips)	1.5T	400	11	1.10 min	2	256	70	Smoothing applied	309	311/11	0.6 mm	4	SENSE-Spine	Surface coil for spine
2	Magnetom-C (SIEMENS)	0.35T	444	18	4:18 min	3	320	90	Medium Smoothing applied	350	100	0.53 mm	4.5	N/A	Phased array surface + body coil

Table 5: Comparison of Parameters of T2w sequence of both modalities.

Following were the Parameters of T2w sequence used for both MRI modalities

Sr. No	MRI Systems	Tesla	TR	TE	Scan Time	NSA/NEX (Avg)	Matrix (Base Resolution)	Phase Resolution	Filter	RFOV	Phase FOV	VOXEL Size	Slice Thickness	SENSE	COIL
1	Achieva (Philips)	1.5T	2210	120	1.50 min	3	256	70	Smoothing applied	309	311/11	0.6 mm	4	SENSE-Spine	Surface coil for spine
2	Magnetom-C (SIEMENS)	0.35T	3350	135	6:30 min	5	320	90		350	100	0.53 mm	4.5	N/A	Phased array surface + body coil

Table 6: Comparison of Parameters of T2w sequence of both modalities.

Discussion

a. Observations by comparing the parameters (Tables 5 & 6) and images (Figures 6-12) of both studies demonstrate that the operator of 1.5T MRI System Achieva (Philips) shorten the scan time by decreasing signal averages (NSA or NEX), matrix size, phase resolution, increasing voxel size and by using IPAT or SENSE technique which leads to poor quality images.

- b. By reducing number of averages (NSA or NEX) decrease the signal to noise ratio and increasing the respiratory motion artifact which leads to blurry images in 1.5T MRI System Achieva (Philips) (Tables 3,5 & 6).
- c. By reduction the matrix size from 320 to 256 & phase resolution to decrease the scan time and also diminish

the resolution by increasing the voxel size (Tables 3, 5 & 6).

- d. In comparison to 0.35T Magnetom-C (SIEMENS) scanners, a SENSE (IPAT) technique) has applied to shorten the scan time which also diminished SNR in 1.5T MRI System Achieva (Philips) (Tables 5 & 6).

Conclusion

This case illustrates the need for using standard protocols with optimal timing of sequence to obtain good quality images with high resolution within acceptable range of SNR for proper diagnosis of small pathologies and metastatic lesions of spine. Many MRI technologists shorten the scan time by decreasing resolution, SNR, signal averages (NSA or NEX) and by using the SENSE (IPAT) technique which leads to blurry or poor resolution images were acquired and information were lost which lead to misdiagnosis. Continuous CME for technologists is needed to keep them abreast of the latest guidelines and techniques to aware of MRI parameters benefits and trade-offs.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

Consent for Publication

Informed consent was obtained from the patient to publish this case in a medical journal.

Ethical Approval

Ethical approval is not required at our institution for publishing a case report in a medical journal.

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