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ORIGINAL ARTICLE

Role of radial k –space sampling technique in non-cooperative patients for the compensation of motion artifact in magnetic resonance imaging (MRI).

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ABSTRACT… Objective: To access the role of radial K-space sampling technique for the compensation of motion artifact in magnetic resonance imaging (MRI). **Study Design:** Systematic Literature Search. **Setting:** Department of Radiology, Shalimar Hospital, Lahore. **Period:** March 2019 to Oct 2019. **Material & Methods:** Was conducted with the help the of following search engines: Google scholar, PubMed, NCBI, Medline and Medscape databases from 1999 up to 2019 for names or acronyms of Radial K-space sampling, propeller sequence, management of motion artifact in MRI, RADAR sequence for motion compensation in MRI, k-space in clinic and multivane. Only those studies were included in this review study which shows the role of radial K-space sampling Technique for compensation of motion artifact. Total 104 studies were selected and after evaluation only 42 studies were included. **Results:** According to literature radial k-space sampling improved the quality of image and provided the scans with reduced motion artifact. Whereas in case of specificity (N= 16) the mean calculated value was 80.87 and Std. Deviation was 7.022. In case of radial k-space sampling technique (N=42) calculated mean was .26 and std. deviation was .701. The main disadvantage of radial k-space sampling is increased scan time. **Conclusion:** After reviewing literature of 42 studies, it was assessed that the use of radial K-space sampling technique or propeller sequence adjacent to the standard MRI sequences can reduce the motion artifact and will increase the image quality.

Key words: K-space Sampling, Motion Artifact, Propeller Sequence, RADAR Sequence, Multivane Sequence.

INTRODUCTION

Magnetic resonance imaging (MRI) is a medical imaging modality that is free from radiation, safe, non-intrusive and has powerful soft-tissues contrast.[1] Since the time of its emergence in early 1980s this imaging modality is believed as the important modality in the domain of diagnostic imaging. MR imaging can provide the morphological details of static objects in the best way possible.[2] Magnetic resonance imaging can be used for clinical evaluation in orthopedics, neurology, cardiology, and oncology to mention a few.[3] In comparison to other medical imaging modalities like computed tomography CT or ultrasound, MRI has always been specifically sensitive to patient motion. Basically, it requires longer time period for collecting adequate data for formation of image in MR imaging. This data acquisition time is more extended than a timescale of mostly physiological motion like involuntary movements, cardiac movements, respiratory motion, vessel pulsation, gastrointestinal peristalsis and CSF and blood flow. All these physiological movements produce motion artifact that lead to blurring of scans.[4] The acoustic noise produced during MR imaging increases the patient discomfort, induce anxiety and increase the probability of artifact but enhancing the susceptibility to bulk motion.[5]

Common practices to avoid motion artifacts are to induce anesthesia in most of uncooperative patients. But anesthesia induction has its limitations like stoppage of breathing, hypoxic neuronal brain damage.[6] According to some recent researches some methods of data

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collection like radial k-space sampling is gaining its importance. The main advantage of using radial k-space sampling is it is making easier to do data acquisition in un-sedated and moving subject. Radial k-space sampling compensates the bulk movements and provides a better image contrast.[7,8]

Traditional techniques of MRI (e.g. SS-FSE, single-shot FSE) lead to blurring and ghosting of scans and produce several other artefacts that not only reduce the quality of scan but also provide less lesion detection. In 1999 Pipe introduced a novel technique PROPELLER (periodically rotated overlapping parallel lines with enhanced reconstruction) or PROP that uses a unique strategy and reduce translational head motion and in-plane rotation by alternate sampling of k-space. PROPELLER uses multiple echo trains in a rotating, partially overlapped fashion with concentric blades that rotate through the center of k-space. Sampling the center of k-space many times in this fashion can itself improve artefact suppression.[9]

This radial k sampling technique provides high resolution and it is less sensitive to motion, due to highly oversampling of the radial k space character and its center. Furthermore, during the reconstruction the strength of the motion can be improved. From the single blade low resolution image regenerate that use in to access the in-plane translation and accurate for the recognized inconsistencies between the blades. Blade with multiple lines allow more exact approximation and correction of motion than blades with fewer lines.[10] Additionally the central disc of k space sampling composed on all the strips and used to observe and accurate the in-plan rotation of the single k space strips. PROPELLER technique has been considered the vital tool for diagnostic information and available with different names on the majority of magnetic imaging platform. Due to stronger oversampling around the k space Centre the time of the image appropriation increased which is the major downside of the PROPELLER and also limited the 2D imaging and strength against the through-plane motions.[11]

MATERIAL & METHODS

Systematic literature search was conducted by the help of following search engines: Google scholar, PubMed, NCBI, Medline and Medscape databases from 1999 up to 2019 for names or acronyms of Radial K-space sampling, propeller sequence, management of motion artifact in MRI, RADAR sequence for motion compensation in MRI, k-space in clinic and multivane. Only those studies were included in this review study which show the role of radial K-space sampling Technique for motion compensation artefact or the studies in which motion independent sequence was selected, that truly work on the physics of Radial filling of k-space.

After independently screening the abstract and titles relevant articles, studies were included if they contain any related information of k-space sampling, MRI trajectories, cause or source of motion artifact that is produced during imaging, reconstruction methods to reduce motion artifact, use of propeller sequence in different anatomical regions and motion sensitive regions of body. Studies investigating both adults and children together were included. The minimum data set required was sample size, anatomical region of the body, role of radial-space sampling technique, imaging indication, imaging time, presence of motion artifact, image quality and pathology Detection. Data were extracted from the full journal article and studies were assessed for applicability and quality. Summary statistics were calculated from the raw data given in the study if they were not reported. Numbers were read from graphs if not reported in the text of the articles.

The search identified a total of 82 original studies, and twenty-two more were selected through hand-searching reference lists and by using the Web of Science cited reference tool. Fourteen studies compared k-space radial sampling MRI techniques to conventional MRI techniques, ten studies reviewed the clinical use of multivane motion independent technique of MRI. Similarly, six studies compared two ultrafast techniques. Four compared ultra-fast and standard MRI to CT, another four studies compared propeller sequence of MRI to standard EPI and one compared an ultra-fast technique to a technique using oversampling of k-space. The included studies are listed in Table-I. In most of the studies participants were children but some adults were also included. Almost in maximum studies comparing motion independent techniques to standard MRI the two sequences were interpreted side by observers. In all studies except of review articles observer were completely blinded to the sequence applied for scanning. All excluded studies are well explained in PRISMA flow chart. In this review study the Data analysis was performed with the help of Microsoft excel 2017 and (SPSS 24, IBM, Armonk, NY, United States of America) Statistical Package for the Social Sciences version 24.

Articles of different languages (Chinese, Japanese etc.) created limitations to access their data to be included in this research.

RESULTS

As literature reviewed shown in Prisma Flow Chart of 104 studies from 1999 to 2019 and only 42 were included in this study it's observed that the Overall effect of motion artifact on image was reduced by using the radial k-space sampling technique. Further analyzing 42 studies the data was categorized on the basis of variables. As sensitivity and specificity were of prime importance and were included in only 16 studies. A forest plot was formed and pooled analysis for mean values was also designed. Descriptive analysis was performed on all other variables and shown in respective table.

PRISMA Flow Diagram of literature searched

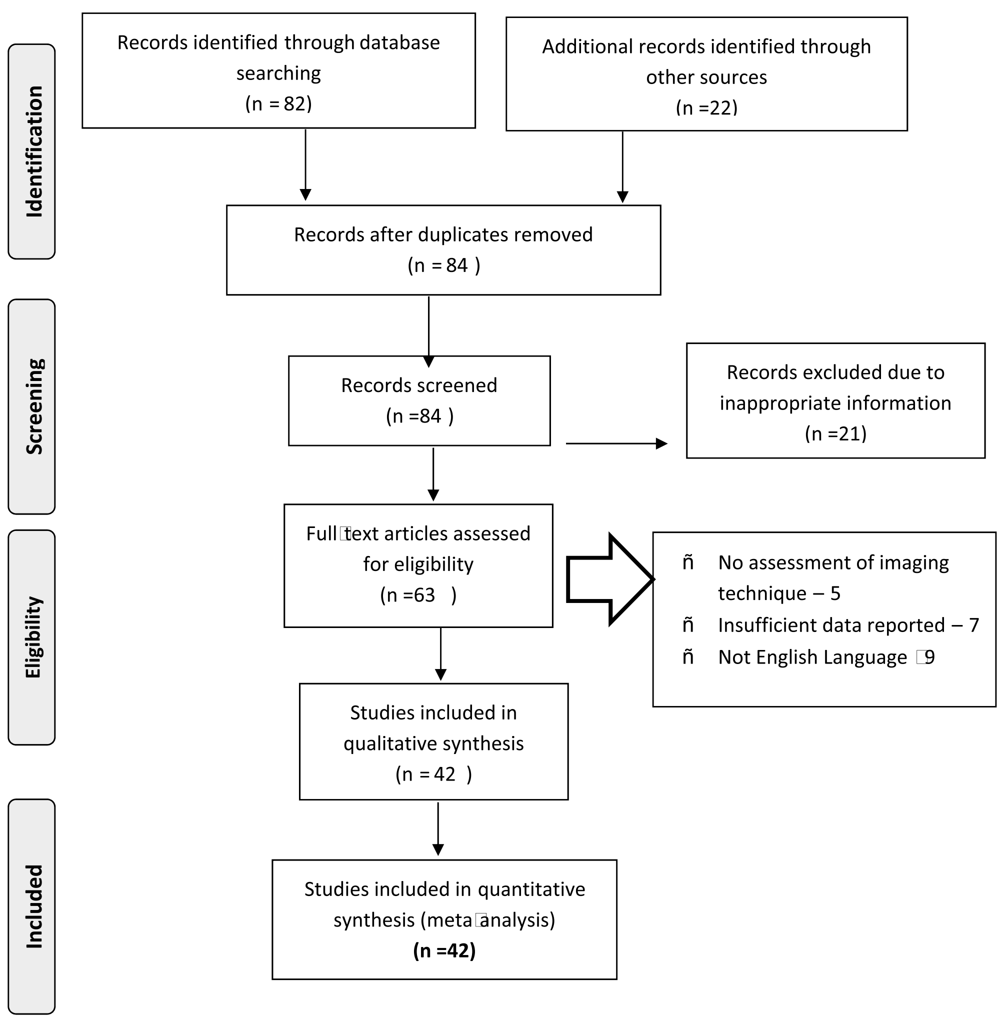

Table-I shows the pooled results of sensitivity and specificity which was extracted from 16 studies. The minimum and maximum sensitivity was 100 so that the range is 0. Same as the standard deviation for sensitivity was zero. Whereas in case of specificity (N= 16) the range calculated by statistical analysis was 26. The minimum specificity was 63 and maximum was 89 the mean calculated value was 80.87 and Std. Deviation was 7.022. A box plot was formed shown in Figure-1. The forest plot in Figure-2. shows the graphical presentation of individual studies.

Table-II shows the statistical description of motion artifact recorded in 42 studies and the comparison of its occurrence in standard imaging technique versus radial K-space sampling technique. While talking about the standard imaging technique the range was 66, minimum percent value was 11 and maximum was 77 whereas the mean calculated value was 31.71 and Std. deviation was 18.4. In case of radial k-space sampling technique (N=42) the range was 3, minimum value was 0 and maximum value was 3, calculated mean was .26 and std. deviation was .7.

Table-III (In this table a data set of forty two (N=42) studies is categorized according to required detail, it is showing that the overall image quality after using radial k-space sampling technique can be improved. same as it is also explaining the increase in imaging time. Further variables are analyzed individually).

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Sensitivity	16	.00	100.00	100.00	100.0000	.00000
Specificity	16	26.00	63.00	89.00	80.8750	7.02258
Valid N (listwise)	16					

Table-I. Pooled sensitivity and specificity

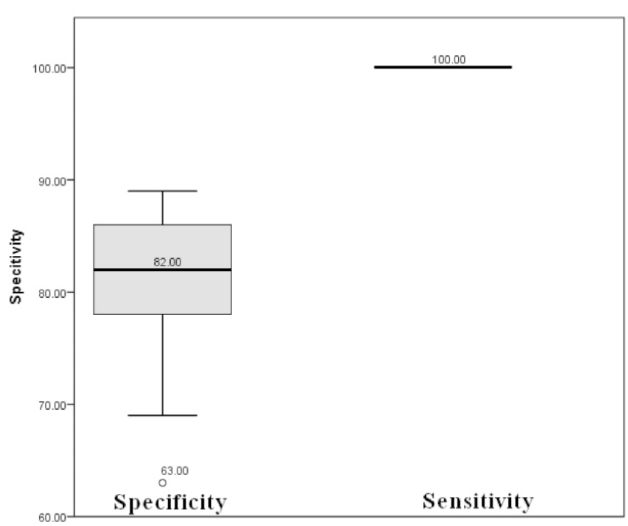

Figure-1. Box plot of pooled sensitivity and specificity

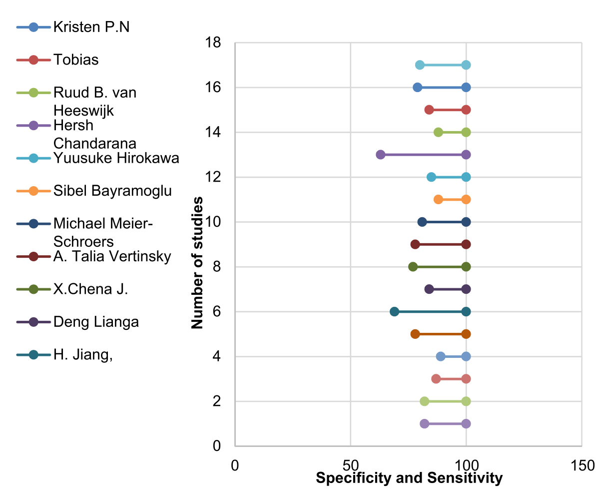

Figure-2. Forest plot for specificity and sensitivity

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Motion_Art_Std in standard technique	42	66	11	77	31.71	18.462
Motion_Art_K_Space sampling technique	42	3	0	3	.26	.701
Valid N (listwise)	42					

Table-II. Motion artifact in standard and radial k-space sampling technique

Author	Imaging Indication	Imaging Time			Presence of Motion Artifact		Image Quality k-space sampling Tech.	Disease	Sensi-tivity	Speci-ficity
		Standard	K-space sampling Tech.	Increased/ Decreased	Standard	K-space sampling Tech				
Kristen P.N[21]	Any referral with motion artifact on standard MRI	3 min 16 s	5 min 50 s	Increased by 2mins	23%	0%	Improved	N/A	100%	79%
Tobias	Any referral with motion artifact on standard MRI	2min 13s	3min 16 s	Increased by 1min	18%	0%	Improved	Rotator cuff tear	100%	84%
E. Nyberg	Any referral with motion artifact on standard MRI	N/a	N/a	N/a	25%	0%	Improved	Neurological disorder	N/A	N/A
Maxim zaitsev[28]	Any referral with motion artifact on standard MRI	N/a	N/a	N/a	18%	0%	Improved	N/A	N/A	N/A
I. Corcuera-Solano[29]	Any referral with motion artifact on standard mri	3mins 2 s	5mins 30s	Increased by 1min	12%	0%	Improved	N/A	N/A	N/A
Harushi Mori.et,al[20]	Any referral with motion artifact on standard MRI	2mins 10sec	4 min 40 s	Increased by 2mins	22%	0%	Improved	N/A	N/A	N/A
Ruud B. Van Heeswijk[30]	Any referral with motion artifact on standard MRI	N/A	N/A	N/A	19%	0%	Improved	Degenerative disk disease	100%	88%
C. Fellner[31]	Any referral with motion artifact on standard mri	N/A	N/A	N/A	11%	0%	Improved	N/A	N/A	N/A
Joe Sperandeo	Application of acquisition parameters on motion correction	4 mins 20s	6min 10s	Increased by 2mins	44%	3%	Improved	N/A	N/A	N/A
Ashish A.[32]	Application of acquisition parameters on motion correction	N/A	N/A	N/A	22%	2%	Improved	N/A	N/A	N/A
James G. Pipe[7s]	Application of acquisition parameters on motion correction	N/A	N/A	N/A	52%	0%	Improved	N/A	N/A	N/A
Hiroaki Shimamoto[33]	Application of acquisition parameters on motion correction	2mins 10sec	4 min 30s	Increased by 2mins	64%	0%	Improved	N/A	N/A	N/A
Hersh Chandarana[13]	Contrsat enhancing lesion	N/a	N/a	N/a	34%	0%	Improved	Hippocampal sclerosis	100%	63%
Jong hyuk lee[34]	Contrsat enhancing lesion	N/a	N/a	N/a	42%	2%	Improved	N/A	N/A	N/A
Sofia H. Eriksson	Contrsat enhancing lesion	2min 13s	3min 20 s	Increased by 2mins	23%	0%	Improved	N/A	N/A	N/A
Deng, jie[23]	Any referral with motion artifact on standard mri	N/a	N/a	N/a	31%	2%	Improved	N/A	N/A	N/A
Yuusuke Hirokawa[14]	Any referral with motion artifact on standard mri	4mins 10se	7mins 20s	Increased by 1min	15%	0%	Improved	Upper abdominal pathologies	100%	85%
Sibel Bayramoglu[15]	Suspected upper abdominal lesions	4mins 10se	7mins 20s	Increased by 2mins	11%	0%	Improved	Lung cancer screening	100%	88%
Michael meier-Schroers[17]	Contrast enhancing lesion	2min 13s	3mins 22s	Increased by 2mins	17%	0%	Improved	Neurological disorder	100%	81%
A. Talia Vertinsky[9]	Any referral with motion artifact on standard mri	2min 13s	3mins 2 s	Increased by 1min	61%	0%	Improved	Solid masses of head & neck	100%	78%
X.Chena J.	Differentiation of lymphomas from carcinomas	N/a	N/a	N/a	22%	0%	Improved	Pituitary adenomas	100%	77%
Omar M. Mahmoud	Differentiation of lymphomas from carcinomas	4 mins 20s	7mins 20s	Increased by 2mins	55%	0%	Improved	N/A	N/A	N/A
Deng liang[26]	Any referral with motion artifact on standard mri	N/a	N/a	N/a	76%	0%	Improved	Orbital pathologies	100%	84%
H. Jiang[35]	Any referral with motion artifact on standard mri	N/a	N/a	N/a	44%	0%	Improved	Prostate cancer	100%	69%
Marcin Czarniecki[36]	Any referral with motion artifact on standard mri	4mins 10se	5mins 30s	Increased by 1min	23%	0%	Improved	Rotator cuff tear	100%	78%
Kazuya Nagatomo[16]	Any referral with motion artifact on standard mri	N/a	N/a	N/a	11%	0%	Improved	Acute cerebral infarction	100%	89%
Kirsten P.[18]	Contrast enhancing lesion	2min 13s	3mins 20s	Increased by 2mins	26%	0%	Improved	N/A	N/A	N/A
Wintersperger[22]	Any referral with motion artifact on standard MRI	2min 13s	3mins 20s	Increased by 1min	31%	0%	Improved	N/A	N/A	N/A
Attenberger[24]	Any referral with motion artifact on standard MRI	N/A	N/A	N/A	28%	0%	Improved	N/A	N/A	N/A
Zhang Ai-lian	Contrast enhancing lesion	N/A	N/A	N/A	46%	0%	Improved	Acute cerebral infarction	100%	87%
Meng Chun-ling	Any referral with motion artifact on standard MRI	3mins 2 s	5mins 20s	Increased by 1min	11%	0%	Improved	N/A	N/A	N/A
Lin Zhang[37]	Any referral with motion artifact on standard MRI	2min 10s	3mins 20s	Increased by 1min	57%	0%	Improved	Upper abdominal pathologies	100%	82%
Mustafa m Almuqbel[38]	Any referral with motion artifact on standard mri	N/a	N/a	N/a	64%	1%	Improved	N/a	N/a	N/a
HyungGi Kim.[39]	Any referral with motion artifact on standard mri	2mins 10sec	3mins 20s	Increased by 1min	33%	0%	Improved	N/a	N/a	N/a
Cynthia B	Any referral with motion artifact on standard MRI	N/A	N/A	N/A	21%	0%	Improved	N/A	N/A	N/A
Julie Woodfield[40]	Any referral with motion artifact on standard mri	2mins 10sec	3mins 22s	Increased by 1min	41%	0%	Improved	N/a	N/a	N/a
Arvidas B.	Any referral with motion artifact on standard MRI	4 mins 13s	7mins20s	Increased by 1min	22%	0%	Improved	N/A	N/A	N/A
TachibanaY[41]	Contrast enhancing lesion	N/A	N/A	N/A	16%	0%	Improved	N/A	N/A	N/A
E.Lavdas et.al[25]	Any referral with motion artifact on standard MRI	2mins 10sec	5mins 22s	Increased by 1min	31%	0%	Improved	Neurological disorder	N/A	N/A
E.Lavdas et.al[42]	Any referral with motion artifact on standard MRI	N/A	N/A	N/A	77%	1%	Improved	Meniscal tear	100%	82%
EleftheriosLavdas et.al[42]	Contrast enhancing lesion	2mins 10sec	5mins 12s	Increased by 2mins	22%	0%	Improved	Degenerative disc disease	N/A	N/A
Fu-Nien Wang	Any referral with motion artifact on standard mri	N/a	N/a	N/a	11%	0%	Improved	N/a	N/a	N/a

DISCUSSION

According to a research conducted by James Pipe et al. presences of motion artifacts in their research was 0% and quality of image was also found to be improved. But this research emphasized some real good benefits of radial k-space sampling for the correction of bulk motion in head scans and cardiac scans of non-cooperating patients.[12] In the results of the study conducted by Harushi et al. it was found that radial k-space sampling has a disadvantage as compare to standard MRI. In standard MRI the scan which take 2mins 10sec in the case of radial k-space sampling it takes 4 min 40 second. Radial k-space sampling improves the quality of scan.[13] According to one of the studies of Kirsten P. Forbes et al. on non-sedated children who underwent brain imaging it was found that radial k-space sampling has its major advantage by providing better image contrast. Otherwise regarding metallic artifacts and detection of anomaly both conventional and radial k-space samplings are equally good. According to numbers that are provided by this study the scan time was increased from 3 min 16 s to 5 min 50 s due to consumption of more time in acquisition of data of here dimensions.[14]

According to results of Wintersperger et al. study radial k-space sampling not only reduce the motion artifact but it also has the ability to improve quality of scan by reducing those ghosts that can dampen the overall quality of image and make them difficult to interpretative for radiologists.[15] Deng, Jie et al. conducted a study and compared the results of conventional MR imaging with the diffusion weighted radial k-space sampling. According to results it was found that radial k-space sampling is highly associated with the better quality of scanning. But it does provide the information that motion artifact of 31% can be reduced to 2% by the use of radial k-space sampling.[16]

YuusukeHirokawa et al. conducted a study that compared respiratory triggered PACE technique with radial k-space sampling in the patients of upper abdomen pathologies. The radial k-space sampling reduces the image artifact from 15% to 0%. According to this research the sensitivity and specificity of radial k-space sampling is 100% and 85% respectively.[17] According to results of the study conducted by A. Talia Vertinsky et al. it was found that radial k-space sampling provides better quality of image and reduces motion artifacts. According to the numbers; scan time by radial k-space sampling is 3mins 2s that is more as compare to 2min 13s of standard MR imaging. The recorded sensitivity and specificity is 100% and 78%, respectively.[18]

Attenberger et al. conducted a study on patients of acute brain ischemia to detect the image quality of scans that were done by radial k-space sampling. According to results it was found that image artifact by radial k-space sampling was found at 0%.[19] According to a study conducted by SibelBayramogluetal. on individuals suffering from pathologies of upper abdomen. It was found that radial k-space sampling eliminated the motion artifact and improved the image quality with the increased scan time of 2minutes as compare to standard MR imaging protocols with sensitivity and specificity of 100% and 88%.[20] According to a study that was conducted by HershChandarana et al. to compare the standard MR imaging with modern radial k-space sampling concluded that modern radial k-space sampling provides better image quality, and lesser motion artifact with sensitivity and specificity of 100% and 63%.[21]

The E.Lavdas et.al study also depicted the sensitivity and specificity of radial k-space sampling; 100% and 82% respectively.[22] According to research that was conducted by Michael Meier-Schroerset al. to detect pulmonary nodules by using radial k-space sampling it was found this technique provided better quality images with sensitivity and specificity of 100% and 18% at an increased scan time of 2minutes. Only streak artifacts were slightly found in the peripheral field of view.[23] According to study that was conducted by Deng Liang et al. the sensitivity and specificity of radial k-space sampling was 100% and 84% respectively. This non-invasive technique of radial k-space sampling not only reduced the motion artifact to 0% but also improved the quality of scan in patients of orbital pathologies.[24]

Another study that showed promising effects of radial k-space sampling was conducted by H. Jiang et al. on the patients who were suffering from prostate cancer. This modern technique not only reduced the motion artifact and enhanced the quality of scan but also provided the sensitivity of 100% and specificity of 69%.[25] A study was conducted by Marcin Czarniecki et al. on the patients of rotator-cuff tear.[26] Just with only disadvantage of increased scan time this technique not only reduced the motion artefact but provided the numerical values foe sensitivity and specificity i.e. 100% and 78% respectively.[27]

CONCLUSION

It is concluded from all literature discussed that multiple techniques are being used to reduce or compensate motion artifact but Radial k-space sampling technique is doing the best. From forty two studies it is justified as radial k-space sampling technique can reduce motion artifact to its maximum limit.

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