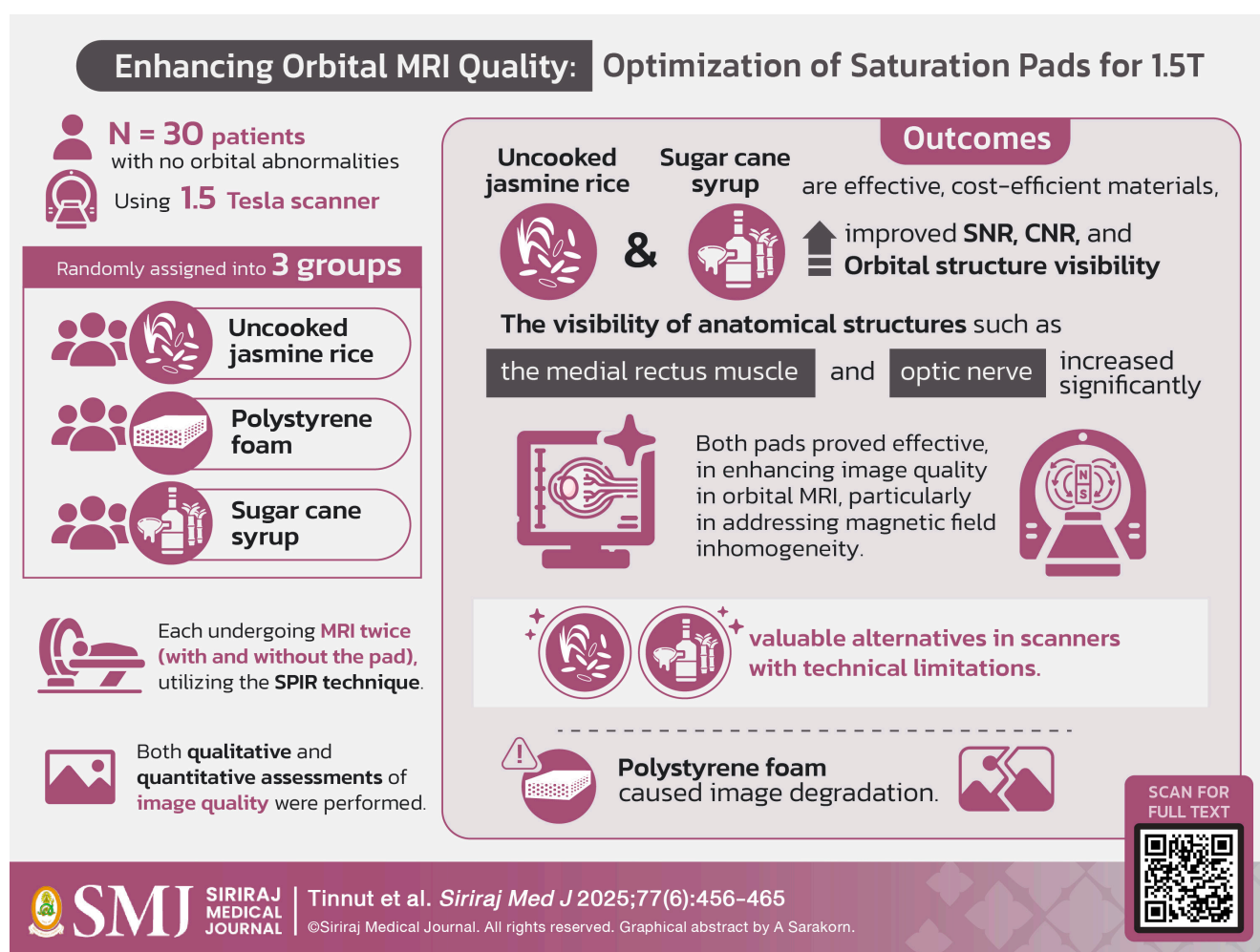


Enhancing Orbital MRI Quality: Optimization of Saturation Pads for 1.5T

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ABSTRACT

Objective: This study aimed to compare the effectiveness of different eye pads in enhancing magnetic field homogeneity using the Spectral Presaturation with Inversion Recovery (SPIR) technique.

Materials and Methods: A prospective study was approved by the Ethics Committee and involved thirty patients undergoing orbital MRI with no current abnormalities. Patients were randomly assigned to one of three groups: uncooked jasmine rice, polystyrene ball bullet foam, or sugar cane syrup. Each patient underwent imaging twice - first without a pad and then with a pad on the eyelid. An experienced neuroradiologist, blinded to pad compositions, evaluated the images quantitatively and qualitatively. Statistical analyses included the Kruskal-Wallis rank test for signal-to-noise (SNR) and contrast-to-noise ratios (CNR), Dunn's test for post-hoc comparisons, the Wilcoxon signed-rank test for qualitative pre- and post-pad differences, and Fisher's exact test for group differences, with significance set at $P < 0.05$.

Results: The uncooked jasmine rice group showed higher SNR and CNR, particularly in the medial rectus muscle (MRM). Significant improvements in the visual scale were noted for the optic nerve sheath complex ($P = 0.002$), MRM ($P = 0.005$), motion artifact ($P = 0.034$), and susceptibility artifact ($P = 0.030$) in both the uncooked jasmine rice and sugar cane syrup groups. Notably, none of the participants in the rice group exhibited a degraded visual scale for MRM or increased susceptibility artifact after pad placement.

Conclusion: This study highlights the effectiveness of uncooked jasmine rice and sugar cane syrup as materials for enhancing orbital MRI quality, especially in earlier scanner models.

Keywords: Fat suppression; Orbit; MRI; Saturation pad; SPIR (Siriraj Med J 2025; 77: 456-465)

INTRODUCTION

Magnetic resonance imaging (MRI) stands out as the preferred modality, offering heightened sensitivity compared to alternative imaging techniques for evaluating the orbit, especially the retrobulbar visual pathway.¹ The coronal plane is favored as it effectively illustrates anatomical relationships.^{2,3} The fat-suppressed sequence becomes an essential and excellent technique for detecting orbital pathology, further distinguishing fat-containing masses from others and leading to a more accurate diagnosis.^{2,4,5}

Currently, there are various techniques for suppressing retrobulbar fat, unique with its own advantages and disadvantages. The Dixon technique is an MRI sequence based on chemical shift, which is designed for uniform fat suppression. It has been growing in popularity due to its advantages over other methods. However, older-generation MRI Scanners still have some limitations. The most effective fat suppression technique for these earlier scanners is Spectral Presaturation with Inversion Recovery (SPIR). SPIR is a hybrid technique that combines both fat saturation and inversion recovery methods. It utilizes a fat-selective radiofrequency pulse and spoiler gradient like chemical shift selective saturation (CHESS), while also nullifying residual longitudinal fat magnetization through an inversion delay mechanism similar to short tau inversion recovery (STIR). However, SPIR still faces challenges due to magnetic field inhomogeneity, particularly

at tissue interfaces. Incomplete fat suppression and darkening in the images due to signal degradation are still common in orbital MRI, especially adjacent paranasal sinuses (air-tissue) and the skull base (bone-tissue). These artifacts adversely affect the image quality and interpretation, posing a challenge, especially in earlier scanners in our department.

Previous studies explored various materials for saturation bags, such as sponge pillows, uncooked rice, acrylic and glass beads, flour, bath salts, perfluorocarbon liquids, and polystyrene and polypropylene beads, to reduce inhomogeneity in MRI scans.⁶⁻¹⁵ Findings from these studies indicated that material such as glass beads, bath salts, polystyrene, rice, and flour were effective in enhancing image quality by minimizing susceptibility artifacts. Notably, while these materials have shown promise, they did not uniformly address the specific challenges associated with orbital imaging, particularly concerning artifacts from adjacent tissues like the paranasal sinuses and skull base. Existing solutions often face limitations in terms of cost, availability, and effectiveness in the orbital region, creating a significant gap in the current literature. In this context, we propose sugar cane syrup as a novel and cost-effective alternative to perfluorocarbon liquid pads for enhancing orbital MRI quality. Our hypothesis is that sugar cane syrup, with its unique rheological and magnetic properties, can provide improved magnetic field homogeneity, thereby enhancing image quality in

the orbital region. This study aims not only to evaluate the effectiveness of sugar cane syrup but also to provide a critical comparison of its performance against established materials, leading to a more comprehensive understanding of potential solutions for optimizing orbital MRI.

The aim of our study was to assess the most effective eye pad for enhancing magnetic field homogeneity within the context of the SPIR technique, specifically focusing on the evaluation of orbital anatomy in the coronal plane. We examined three materials—uncooked jasmine rice, polystyrene ball bullet foam, and sugar cane syrup—selected for their convenience, affordability, and the inconclusive results from previous research. Each material exhibits distinct diamagnetic properties, which may lead to varying degrees of improvement in image quality.

MATERIALS AND METHODS

Patient Population

This descriptive prospective study was approved by the IRB No.P3-0015/2564. Thirty patients who underwent orbital MRI at our department between June 7, 2021 and June 10, 2023 and had no current orbital abnormality were recruited. All patients gave informed consent prior to participation in this study. Using a simple random sampling technique (lottery method), the patients were categorized into three groups: uncooked jasmine rice group, polystyrene ball bullet foam group, and sugar cane syrup group.

Image acquisition

All patients were scanned on a 1.5 Tesla MRI scanner (Philips Ingenia, Philips Medical Systems, Best, the Netherlands), release 4.1.3.3 software version (installed August 2014) using a conventional head array coil. A coronal spin-echo T2-weighted (T2W) sequence was acquired with the following parameters: TR = 3000 msec, TE = 70 msec, FOV 130x149 mm, 3 mm slice thickness, number of signal acquisitions = 2, 216x210 matrix size, and shim mode = auto shimming. The shim values were automatically selected based on the MRI scanner's shimming algorithm within the imaging FOV. For each patient, a T2W coronal image with fat suppression technique was acquired twice: 1) with nothing on the eyelids, and 2) with a pad placed on the closed eyelid (Fig 1). The SPIR technique was used to suppress fat signals in orbital MRI.

Pad design

This study utilized uncooked jasmine rice, polystyrene ball bullet foam, and sugar cane syrup, which were utilized to enhance the magnetic field. The bags, constructed from latex material, were safe (i.e., nontoxic and nonirritating),

and posed no adverse effects within the magnetic field. Fig 2 illustrates a small, round latex rubber balloon (4 inches in diameter) filled with these materials. The jasmine rice bag, which weighed 65.05 g, contained long-grain, opaque white grains. The polystyrene ball bullet foam was spherical and measured 2 mm in diameter, with the foam bag weighing 3.72 g. The sugar cane syrup bag weighed 58.08 g, prepared at a concentration of 77 Brix solution. At 20°C, 1 Brix is equivalent to 1 g of sugar in 100 g of water and sugar solution. This solution contains 1.08 kg of sugar per one liter of water and the cane syrup will had a density value of 1.39 g/L. All pads were standardized to have a uniform size and shape, regardless of fill material. A visual inspection was conducted before usage to identify potential issues such as leaks, damage, or other defects.



Fig 1. The figure illustrates the placement of the saturation pad on the patient's eye in relation to the conventional head array coil.

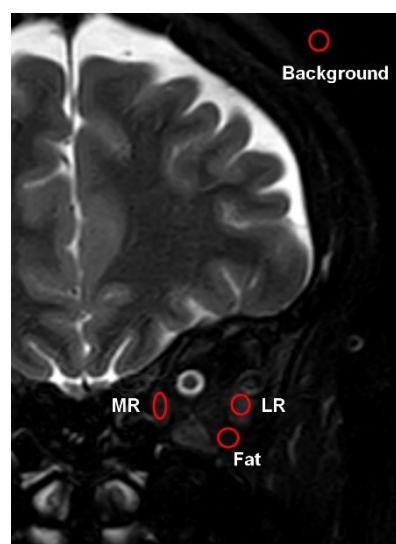


Fig 2. Quantitative assessment of normal intraorbital anatomy was conducted by drawing a red circle respecting anatomical borders, covering approximately 0.1 cm². This method included labeling the medial rectus (MR), lateral rectus (LR), and intraconal fat, and background area.

Image evaluation

All included patients, both with and without placed saturation pads, were reviewed by a neuroradiologist with 5 years of experience who was blinded to the material composition of the pads. Both qualitative and quantitative assessments of normal intraorbital anatomy were performed before and after pad placement.

The signal intensity (SI) of anatomy was measured using a circular region of interest (ROI) for quantitative assessment. The size of the ROI area was standardized in the coronal plane, and precisely drawn to be 0.1 cm² with respect to anatomical borders, at the medial rectus muscle (MRM), lateral rectus muscle (LR), inferolateral extraconal fat, and background (Fig 3). The signal-to-noise ratio (SNR) was measured by calculating the mean SI within a region of interest (MRM, LR, and fat) and dividing it by the standard deviation of the noise in a background area (the air) where no signal is present. Contrast-to-noise ratio (CNR) was measured by calculating the mean SI of two different ROIs (MRM/fat and LR/fat) within the image and dividing them by the standard deviation in a background area (the air).

For qualitative assessment, a five-point numeric scale was used to evaluate the visibility of structures: 1, non-visualization; 3, indeterminate; and 5, definite visualization.¹⁶ Both normal orbital anatomy and pericavernous structures were evaluated, including optic nerve sheath complex (ON), superior ophthalmic vein (SOV), MRM, LR, inferior rectus muscle (IR), dural reflection, Meckel's cave, pituitary gland, and temporal lobe. Magnetic susceptibility due to the paranasal sinuses and mastoid air cells, motion artifact due to head and globes movement were also rated on a five-point scale: 1, indicates blurring of surrounding structures due to artifact; 3, artifact is present, but structures are distinguishable; and 5, no artifact.¹⁶ The visual assessment scale is illustrated in Fig 4.

Statistical analysis

All statistical analyses were performed using Stata version 17.0. Demographic numerical data were displayed as the mean and SD, whereas categorical data were represented by frequencies and percentages. To compare the three different pad groups, we used analysis of variance



Fig 3. The pads were created by filling small latex bags with various materials: polystyrene ball bullet foam (left), uncooked jasmine rice (middle), and sugar cane syrup (right). The images show the materials before filling the pads (top row) and the completed pads (bottom row).

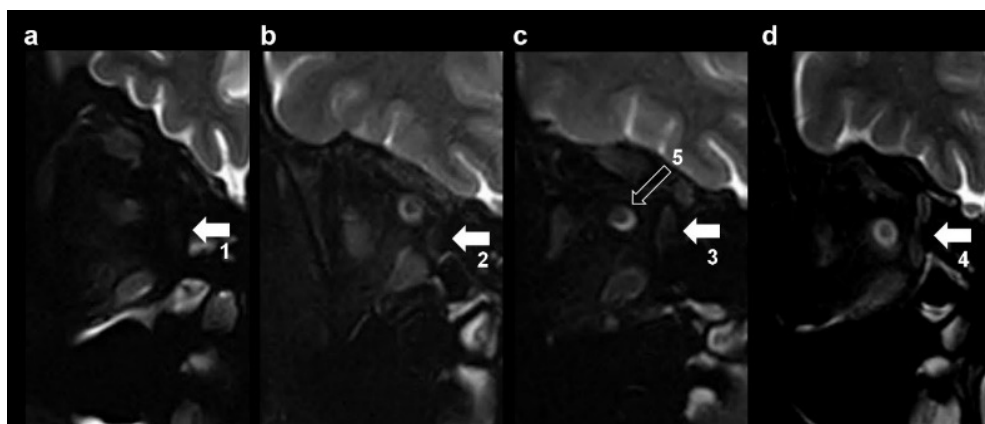


Fig 4. Coronal T2W images of the orbit illustrate the visual assessment scale ranging from 1 to 5 (a–d). In image “a,” the medial rectus muscle (MRM, arrow) is rated as 1, indicating it is non-visualized, totally obscured by artifact. In image “b,” it is rated as 2, with the margins of the MRM not clearly demarcated. In image “c,” the MRM shows a rating of 3, displaying visible artifacts but distinguishable structures; however, signal intensity cannot be assessed. In image “d,” the rating is 4, indicating that signal intensity can be assessed despite minimal artifacts. Additionally, the optic nerve (ON, open arrow) in image “c” is rated as 5, indicating exceptional clarity and absence of artifacts. This assessment is based on the criteria outlined in the study.

and the Fisher's exact test. For quantitative assessment, the Kruskal–Wallis rank test and a post-hoc test were used, and the results were presented as medians and interquartile range (IQR). The significance level was set at less than 0.05. For the qualitative analysis, we calculated the differences in scale between before and after pad placement for each patient, orbit, and anatomical structure. The ordinal data were presented as frequencies and proportions. Fisher's exact test was used to test for significant differences among the groups of three material pads. A p-value of 0.05 or less is considered statistically significant.

RESULTS

The mean ages of patients in each group were as follows: 52.50 ± 16.08 for the uncooked jasmine rice group, 45.20 ± 14.76 for the polystyrene ball bullet foam group, and 58.40 ± 17.49 for the sugar cane syrup group. In the uncooked jasmine rice group, there was an equal number of male and female patients, with 5 individuals in each category. The polystyrene ball bullet foam group had 7 males and 3 females. The sugar cane syrup group had 4 males and 6 females. Table 1 shows that there are no

significant differences in patient characteristics among the groups.

Orbital anatomy

The uncooked jasmine rice group exhibited notably higher SNR and CNR, particularly in the MRM, when compared to the other two groups (Table 2). However, there was no significant difference observed in the MRM and LR for quantitative assessment, as determined by the Kruskal–Wallis rank test and a post-hoc test.

Visual scale improvements were evident in both the uncooked jasmine rice and sugar cane syrup groups (Fig 5). In particular, the uncooked jasmine rice group demonstrated a significant increase in visibility of the ON at 95% ($P = 0.002$), motion artifact at 55% ($P = 0.034$), and susceptibility artifact at 95% ($P = 0.030$). Meanwhile, the sugar cane syrup group displayed a remarkably enhanced visibility of the MRM at 95% ($P = 0.005$). Although the remaining orbital structures (SOV, LR, and IR) showed trends toward improved visibility in the sugar cane syrup group, no statistically significant difference was observed. The results are presented in Table 3.

TABLE 1. Demographic data.

Variable	Uncooked Jasmine Rice	Polystyrene Ball Bullet	Sugar Cane Syrup	P-value
Age (year), mean $\pm$ SD	52.50 $\pm$ 16.08	45.20 $\pm$ 14.76	58.40 $\pm$ 17.49	0.206
Sex, N (%)				0.534
Female	5 (50.0)	7 (70.0)	4 (40.0)	
Male	5 (50.0)	3 (30.0)	6 (60.0)	

TABLE 2. Quantitative assessment of orbital structures.

Quantitative assessment Median (IQR)	Uncooked Jasmine Rice	Polystyrene Ball Bullet	Sugar Cane Syrup	P-value
SNR Medial rectus muscle	4.85 (0.45-14.45)	2.75 (0.20-6.95)	3.40 (2.95-8.55)	0.402
SNR Lateral rectus muscle	2.75 (2.25-10.40)	2.70 (2.30-6.10)	1.60 (0.39-4.60)	0.384
SNR Inferior extraconal fat	0.55 (0.25-5.15)	1.55 (0.55-2.40)	0.05 (0.00-3.45)	0.428
CNR Medial rectus muscle	0.30 (0.05-0.65)	0.20 (0.00-0.70)	0.15 (0.03-0.35)	0.409
CNR Lateral rectus muscle	0.15 (0.00-0.8)	0.00 (0.00-0.55)	0.15 (0.08-0.15)	0.255

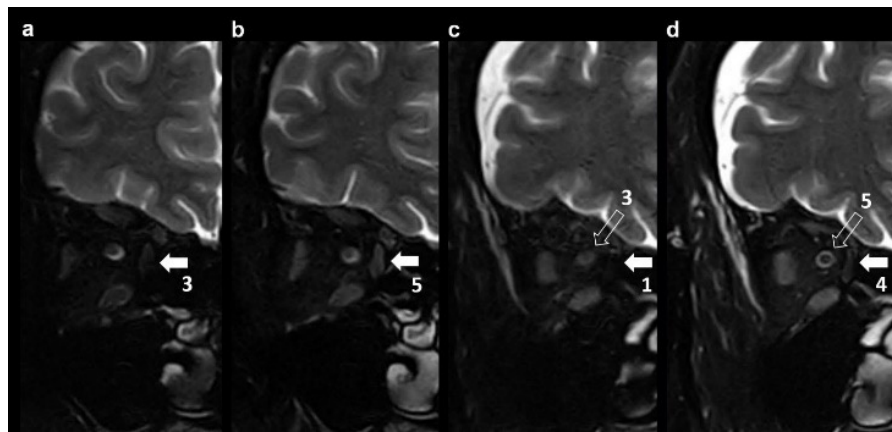


Fig 5. Coronal T2W images demonstrate the improvement in visibility of the medial rectus muscle (MRM, arrow) and optic nerve (ON, open arrow) before and after pad placement, as assessed by a quantitative scale. In the sugar cane syrup group (a, b), MRM visibility increases from 3 to 5. In the uncooked jasmine rice group (c, d), MRM visibility increases from 1 to 4, while ON visibility improves from 3 to 5. These results highlight the effectiveness of the two pad materials in enhancing image quality.

TABLE 3. Visual assessment of orbital structures.

Orbital structures N (%)	Uncooked Jasmine Rice	Polystyrene Ball Bullet	Sugar Cane Syrup	P-value
Optic nerve-optic sheath complex				
Improvement	19 (95.0)	9 (45.0)	14 (70.0)	0.002*
No change	0 (0)	3 (15.0)	2 (10.0)	0.353
Degradation	1 (5.0)	8 (40.0)	4 (20.0)	0.024*
Superior ophthalmic vein				
Improvement	11 (55.0)	8 (40.0)	12 (60.0)	0.521
No change	4 (20.0)	4 (20.0)	2 (10.0)	0.749
Degradation	5 (25.0)	8 (40.0)	6 (30.0)	0.692
Extraocular muscles				
Medial rectus muscle				
Improvement	18 (90.0)	10 (50.0)	19 (95.0)	0.005*
No change	2 (10.0)	4 (20.0)	0 (0)	0.150
Degradation	0 (0)	6 (30.0)	1 (5.0)	0.013*
Lateral rectus muscle				
Improvement	14 (70.0)	9 (45.0)	15 (75.0)	0.126
No change	4 (20.0)	6 (30.0)	2 (10.0)	0.346
Degradation	2 (10.0)	5 (25.0)	3 (15.0)	0.572
Inferior rectus muscle				
Improvement	16 (80.0)	14 (70.0)	18 (90.0)	0.346
No change	3 (15.0)	1 (5.0)	0 (0)	0.310
Degradation	1 (5.0)	5 (25.0)	2 (10.0)	0.246
Motion artifact				
Improvement	11 (55.0)	3 (15.0)	6 (30.0)	0.034*
No change	7 (35.0)	5 (25.0)	8 (40.0)	0.698
Degradation	2 (10.0)	12 (60.0)	6 (30.0)	0.004*
Susceptibility artifact				
Improvement	19 (95.0)	12 (60.0)	16 (80.0)	0.030*
No change	1 (5.0)	4 (20.0)	3 (15.0)	0.505
Degradation	0 (0)	4 (20.0)	1 (5.0)	0.115

*Statistically significant

Furthermore, our study identified a degraded visual scale for all orbital structures in the polystyrene ball bullet foam group. Specifically, the visual scale of the ON, MRM, and motion artifact was significantly degraded. In the uncooked jasmine rice group, no participant showed a degraded visual scale of the MRM and susceptibility artifact after pad placement.

Pericavernous structures

There was no statistically significant difference observed for pericavernous structures among all three groups. Table 4 illustrates the percentage distribution of each structure across the groups.

DISCUSSION

The importance of fat suppression techniques in enhancing the visibility of orbital pathology is undeniable. SPIR is commonly utilized in Philips scanners as the default method due to its use of RF pulses and inversion recovery to suppress fat signals while maintaining signals from other tissues. However, the effectiveness of fat suppression remains dependent on the uniformity of both the main magnetic field (B0) and the radiofrequency magnetic field (B1) due to the combined CHESSE technique. The persistent issue of orbital MRI is the inhomogeneity caused by tissue interfaces, which can limit diagnostic accuracy. Using material pads is a valuable method to

TABLE 4. Visual assessment of pericavernous structures.

Pericavernous structures N (%)	Uncooked Jasmine Rice	Polystyrene Ball Bullet	Sugar Cane Syrup	P-value
Dural reflection				
Improvement	20 (100.0)	18 (90.0)	18 (90.0)	0.532
No change	0 (0)	1 (5.0)	0 (0)	1.000
Degradation	0 (0)	1 (5.0)	2 (10.0)	0.766
Meckel's cave				
Improvement	13 (65.0)	12 (60.0)	15 (75.0)	0.698
No change	6 (30.0)	6 (30.0)	5 (25.0)	1.000
Degradation	1 (5.0)	2 (10.0)	0 (0)	0.766
Pituitary gland				
Improvement	19 (95.0)	20 (100.0)	20 (100)	1.000
No change	0 (0)	0 (0)	0 (0)	1.000
Degradation	1 (5.0)	0 (0)	0 (0)	1.000
Motion artifact				
Improvement	18 (90.0)	16 (80.0)	16 (80.0)	0.749
No change	2 (10.0)	0 (0)	1 (5.0)	0.766
Degradation	0 (0)	4 (20.0)	3 (15.0)	0.144
Susceptibility artifact				
Improvement	8 (40.0)	5 (25.0)	11 (55.0)	0.174
No change	11 (55.0)	15 (75.0)	9 (45.0)	0.188
Degradation	1 (5.0)	0 (0)	0 (0)	1.000
Temporal lobe				
Improvement	18 (90.0)	12 (60.0)	16 (80.0)	0.099
No change	2 (10.0)	8 (40.0)	2 (10.0)	0.370
Degradation	0 (0)	0 (0)	2 (10.0)	0.322

address this issue and enhance image quality, especially when dealing with limited scanners.^{9,11,14,15,17}

In our study, we enrolled 30 patients who underwent MRI and had no orbital abnormality. We found that the uncooked jasmine rice was more effective than other materials for improving image quality, which is supported by prior research.^{6,10,12} This improvement was particularly notable in the ON, with a significant reduction in both motion and susceptibility artifacts. However, these findings contrast with the study by Teshigawara et al. that explored five pad materials for fat suppression in a breast-simulated phantom using a 3D T1W sequence.⁷ Their result did not identify rice as the optimal pad material. The discrepancies between our results and theirs may arise from the differences in imaging sequences and the use of phantom studies. Additionally, the aspect of material discomfort in their study may have influenced the different outcomes.

The improvement of MRM visualization, which was often obscured by susceptibility artifact from the nearby paranasal sinuses, revealed a significant difference among the three groups. The results showed a 95% improvement in the sugar cane syrup group and a 90% improvement in the uncooked jasmine rice group. However, the trend was reversed for susceptibility artifact improvement, which could be explained by the susceptibility values of materials. In addition, all three materials have diamagnetic properties. Their magnetic susceptibility values are small and slightly negative, within the range of 10^{-6} to 10^{-7} . Uncooked rice has an estimated magnetic susceptibility of -8.2×10^{-7} emu (with 1 emu equal to 1 cm^3), while polystyrene has a susceptibility of -7.5×10^{-6} emu.^{6,18} The susceptibility value of rice is similar to that of human tissue (-11×10^{-6} to -7×10^{-6} emu).¹⁹ It is possible that diamagnetic susceptibility interactions can result in minimal variations in the precession frequency of protons, leading to intravoxel inhomogeneity and chemical shift variation. The effect of susceptibility differences becomes apparent in the behavior of diamagnetic substances when placed in a magnetic field. However, further studies are necessary to better clarify the susceptibility-induced artifacts of diamagnetic substances.

Furthermore, our study also found a significantly degraded visual scale of the ON and MRM in the group of polystyrene ball bullet foam because of increased motion artifacts. This suggests that polystyrene ball bullet foam may not be a suitable material, as it resulted in degraded visibility of all intraorbital structures. This could result from the lightweight nature of the polystyrene ball bullet pad, and it potentially has less surface contact with the eyelid compared to the others, further causing field inhomogeneity

and motion, affecting the image quality. In contrast, the study by Ikeguchi et al. evaluated fat suppression in six healthy volunteers who performed MRI of the head and neck.²⁰ Their findings indicated that the improvement of fat suppression using the STIR technique was similar among all three pads (commercial pad, uncooked rice, and polystyrene ball bullet). However, inconsistency may be attributed to variations in anatomical location, differences in the criteria for the visual assessment scale (using 4-point scales), and the smaller sample sizes in their studies. Despite these promising results, several questions remain unanswered. Future research should focus on refining these techniques to enhance diagnostic accuracy and image quality, particularly in the context of pathological cases where precise imaging is crucial. Modern MRI scanners, equipped with advanced hardware and software, offer opportunities to address challenges such as subtle lesion detection, artifact minimization, and tissue differentiation.

Limitations

This study had several limitations. First, we focused on a single sequence (T2W) and a single imaging plane (coronal) using a 1.5 T magnet. The degree of artifacts may vary based on the technique used, but we respectfully acknowledge that our protocol and setup represent common practices observed in many hospitals using Philips scanners. Second, we used a qualitative assessment using a 5-point scale, ranging from 1 (blurry due to artifacts) to 5 (completely clear with no artifact), which could introduce some subjectivity. However, we believe this visual scale allowed us to capture degrees of uncertainty better than previous studies. Third, the window levels and widths of the images were not set consistently²¹, which could potentially impact interpretation. Fourth, the potential influence of inflammatory mucosal changes in the paranasal sinuses, particularly in the ethmoid and maxillary sinuses, on the magnetic field homogeneity was not accounted for in our study. Fifth, as only one radiologist reviewed the images, the generalizability of our findings might be limited. Involving multiple radiologists could provide a diverse perspective and enhance the reliability of the results. Sixth, the radiologist was unblinded in the group of sugar cane syrup because the images of the anterior globe and eyelids were not obscured, which introduced bias into the assessment. Seventh, while saturation pads may not be considered cutting-edge technology and are less commonly utilized in modern scanners with advanced fat suppression techniques such as the Dixon technique, their value remains significant for enhancing image quality in older MRI scanners limited to basic fat

suppression methods like STIR or SPIR. Finally, it is important to note that we only evaluated patients with presumed normal orbital structures. We hope this result serves as a useful baseline for future research on patients with orbital pathologies. To address the subjective nature of the visual assessment, we suggest developing validation methods in future studies to improve reliability and usefulness.

CONCLUSION

This study highlights the utility of uncooked jasmine rice and sugar cane syrup as effective pads for improving image quality in orbital MRI. These findings provide a practical and affordable solution for addressing inhomogeneity, particularly in scanners with technical limitations.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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DECLARATION

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Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Registration Number of Clinical Trial

None.

Author Contributions

Conceptualization: S.T., K.A.; Methodology: S.T., K.A., K.J.; Data collection: S.T., K.J.; Formal analysis: K.J.; Writing – original draft preparation: S.T.; Writing – review and editing: S.T., K.A., K.J.

Use of Artificial Intelligence

We use ChatGPT exclusively to check English language and sentence structure in the manuscript, without contributing to any other parts of the content.

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