

# Qualitative and Quantitative Comparison of Infant Brain Mri Quality: Feed and Wrap Technique Versus Sedation - Single Centre Experience

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## Research Article

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# Abstract

**Purpose:** “Feed and wrap” (F&W) technique refers to the use of feeding and swaddling to induce natural sleep in infants in order to facilitate MRI scan acquisition without sedation. In our study we aim to evaluate the efficacy of this technique in newborns with clinical suspicion of hypoxic-ischemic encephalopathy (HIE), through a quantitative and qualitative evaluation of infant MRI brain images. **Materials and methods:** in this retrospective, observational, single center study, infant brain MRI scans were performed between February 2018-February 2020. Quantitative evaluation has been defined as the analysis of measurement of the signal to noise ratio (SNR) and contrast to noise ratio (CNR) in the T2 FSE, T1 SE, 3D-TFE, DWI (b1000) sequences with the use of regions of interest (ROI). Qualitative evaluation has been assessed as quality of the whole images, the assessment of motion artifact and spatial resolution with the use of Likert Scale. **Results:** 210 scans have been analyzed, 74% performed under sedation and 26% with F&W technique. Qualitative analysis showed that 80% of F&W scans were partially or fully diagnostic against a predictable diagnostic effectiveness of 99.3% of MRI scans during sedation. Quantitative analysis showed comparable SNR and CNR values between the two populations in DWI and T2w (only in basal ganglia), while 3D-T1 showed significantly lower CNR and SNR values in the F&W MRI scans. Additionally, T1-SE CNR was comparable between F&W scans and under sedation. **Conclusion:** considering the good quality of brain MRI scans, the F&W technique can be used effectively to detect diagnostic features of HIE.

## INTRODUCTION

In recent years, MR Imaging has assumed a pivotal role in evaluating infants’ central nervous system (CNS) diseases and, currently, it represents a fundamental safe and non-invasive method in the examination of human brain, treatment planning and prognostic assessment of the infant. MRI demonstrated high sensitivity in detecting acute anoxic injury of neonatal brain [1] providing detailed information on lesion patterns. Moreover, conventional MR sequences are highly predictive of outcomes [2–3]. Currently, MRI is the standard of care for term infant hypoxic ischaemic encephalopathy (HIE) who undergo whole-body cooling.

Despite its safety, performing MRI in infants presents numerous challenges. MRI is highly sensitive to motion, requiring that newborns remain still during the scan, which in clinical practice usually lasts 15–40 minutes, depending on MR scanner, protocol and sequences acquired. This requirement poses significant difficulties in the pediatric population, resulting in motion artifacts and image degradation. To address these challenges and reduce stress and motion in newborns, several approaches have been developed.

The conventional approach is patient sedation, but this method is associated with additional risks and costs [4]. Sedation can add and lead to short term risks related to under-sedation or over-sedation and less known long-term effects.

“Feed and wrap” (also known as “feed and sleep” or “feed and swaddle”) is an alternative method used for MR examinations in infants’ younger than 6 months of age, without sedation [5].

In the feed and wrap method, food, comfort, and warmth are used to induce natural sleep, and swaddling is used to reduce motion artifacts.

Mathur et al. [6] were among the first to develop guidelines for non-sedated MRI in neonates, emphasizing close collaboration between neonatal care and radiology teams, including nurses, MRI technologists, and radiologists. More recently Antonov et al [7] demonstrated that a standardized “feed and wrap” technique performed by experienced personnel may avoid the need for anesthesia or sedation in young infants requiring MRI.

We conducted a retrospective study in a group of patients younger than 4 months who received MRI scans at Radiology Department of “A. Gemelli” University Hospital Foundation IRCSS over a 2-year period for the clinical indication of HIE. The scans were performed using either the “feed and wrap” technique or sedation.

Our hypothesis was that MRI performed with “feed and wrap” technique would provide reliable imaging for the evaluation of infants with clinical suspicious of HIE yield clinically meaningful diagnostic information.

## **METHODS**

### **Subjects and data acquisition**

Our Institutional Review Board approved this retrospective single-center study (Prot. N. 0018343/23).

From our institution database we identified all infant brain MRI studies between February 2018 and February 2020. All patients were hospitalized in the Neonatal intensive and sub-intensive Care, Neonatal Pathology, Pediatric intensive care, and Pediatric department of our hospital. Patient characteristics including gender, age at time of scan in days, gestational age, whether inpatient or outpatient, indication for MRI, comorbidities, as well as difficulties arising during scanning (e.g. clinical condition) and MRI scan repetition were recorded.

Infants were deemed eligible for the procedure by the referring physician or neonatal ICU team.

Contraindications to the “feed and wrap” procedure included the use of nitric oxide (since the reservoir is unsafe with MRIs), infants with feeding difficulties and those at risk of respiratory compromise. Immediately before the scan, the baby was fed with breastmilk or infant formula.

Babies were wrapped in swaddling clothes, folded in half diagonally and layered on top of each other in preparation for swaddling making sure that it didn’t contain microchips in the seams that could generate MRI artifacts. Sometimes a pacifier with or without sucrose oral solution (Sweet-Ease) has been used to

help induce natural sleep. An experienced pediatric nurse and MRI technician performed all procedures. Before proceeding with swaddling, we removed any electrodes on the chest or elsewhere.

The oral administration of melatonin was foreseen, in correspondence with the meal, according to the following dosage:

- • three days before the scan (0,2 mg/Kg);
- • two days before the scan (0,3 mg/Kg);
- • one day before the scan (1 mg);
- • 30 minutes before the scan (2 mg), possibly before the feed needed to induce natural sleep

Dimmed lights at the MRI site and around the facility, when carrying the sleeping child, were also carried out. No vital signs monitoring device was used, the presence of which could have facilitated the awakening of the young patients.

All patients underwent MRI imaging of the brain at 1.5 T (INGENIA Philips® Healthcare) with head 8-channel coil or pediatric Head-Spine Coil. The routine imaging protocol at our institution includes axial and coronal T2w TSE, axial T1w SE, axial DWI (diffusion weighted imaging), axial SWI (susceptibility weighted imaging) and sagittal T1w 3D-TFE [Table 1].

All MR imaging data were extracted from the PACS, transferred to an off-line workstation and anonymized for analyses.

### **Quantitative image analysis.**

Quantitative analysis was performed by two senior neuroradiologists (VT and SC with respectively 12 and 10 years of experience). As a quality indicator of medical images, signal-to-noise ratio (SNR) was used with the “two-region” approach, based on the signal statistics in two separate regions of interest (ROIs) from a single image [8–10].

One is the tissue ROI which determines the signal, and the other ROI is localized in the object-free region which measures the noise. For each examination, ROI of equal size (100–150 mm<sup>2</sup>) were drawn for each patient in correspondence of: (1) lentiform nucleus (SGM) and (2) centrum semiovale (SWM). NOISE has been evaluated with ROIs drawn in the background, 5 mm away from the outer edge of the skull, avoiding aliasing and ghosting artifact and eye movement [Fig. 1]

Measurements were performed on axial T2w TSE, T1w SE, DWI (b1000), and on axial reconstructions of 3D-T1w TFE sequences. The background noise ROIs of the 3DT1w TFE sequence were drawn in the sagittal plane of the original sequence, avoiding multiplanar reconstructions because this could have created altered values from the reconstruction itself. For each sequence the SNR has been obtained, starting from the mean values measured at the ROI in the white matter (SWMMEAN) and in the grey matter (SGMMEAN), divided by the standard deviation of the background noise (SNOISEDS) [8–10].

As an extension of the SNR, and measure of scanner performance, we also calculated the contrast-to-noise ratio (CNR).

The CNR has been defined as the difference between the mean values of the ROI drawn in the grey matter (SGMMEAN) and in the white matter (SWMMEAN) divided by the standard deviation of the background noise (SNOISEDS) [11].

### **Qualitative analysis.**

Blinded and independent evaluation was performed by two juniors (radiology residents) and two senior neuroradiologists (VT and SC with respectively 12 and 10 years of experience) reviewed images of all patients. Inter-rater agreement was estimated; cases of disagreement were resolved by consensus. According to Sirin t al. [12] and Muller et al. [13] diagnostic quality of images, assessment of spatial resolution and motion artifact were evaluated. Assessment of diagnostic quality has been evaluated with five-point Likert Scale (1–5) on all sequences, to categorize images as (1) non-diagnostic, (2) poor (partly no diagnostic), (3) moderate (fully diagnostic), (4) good and (5) excellent. Spatial resolution of T2 TSE, 3D-T1w and T1 SE was assessed by scoring using the same five-point Likert-Scale (1–5) based on overall delineation of basal ganglia, temporal sulci, the beginning of brainstem myelination and corticomedullar differentiation of the central sulcus. In patients with pathological alteration of the above-mentioned structure, image quality and spatial resolution were either scored in unaffected region or not scored at all.

Additionally, motion artifacts were scored on all sequences on a three-point Likert-Scale (1–3) as (1) non or not relevant, (2) relevant but diagnostic and (3) non diagnostic [12] **[Table 2]**.

All data were analyzed with dedicated software (SPSS for Windows, v.27.0; IBM, Chicago, IL, USA).

Continuous variables were evaluated by tests of Kolmogorov-Smirnov and Shapiro-Wilk, which showed a normal distribution of the variables examined (SNR and CNR). Student's t-test was applied for the analysis of continuous variables (SNR and CNR) in paired samples and the chi-squared test for the categorical variables (Likert scales). Cohen-k test was used to measure interobserver agreement. Subgroup analysis was performed as needed. The data were considered statistically significant with  $p < 0.05$ .

## **RESULTS**

In total, 231 scans were identified in the period between January 2018 and February 2020, including patients younger than 4 months of age at the time of imaging. 21 scans were excluded from the population, due to the coexisting congenital brain malformations.

Of the 210 patients, 74% of scans were performed during sedation, while 26% with the feed and wrap technique.

As regards the 3DT1 volumetric sequence, the CNR and SNR values - measured in the white matter and in the basal ganglia - were found to be significantly lower in the Feed and Wrap MRI scans, compared to those acquired under anesthesia (average CNR 62,22(N) vs 37,68 (FW)  $P=.001$ ; average SNR\_SGM 112,31 (N) vs 66,61 (FW)  $P=.001$ ; average SNR\_SWM 71,56 (N) vs 41,94 (FW)  $P=.001$ ). [Fig. 2].

On the other hand, the DWI images of the Feed and Wrap population showed CNR and SNR values, in the white matter and in the basal ganglia, completely comparable with the scans acquired under sedation (average CNR 7,38 (N) vs 7,96 (FW)  $P=.719$ ; average SNR\_SGM 27,26 (N) vs 24,70 (FW)  $P=.369$ ; average SNR\_SWM 22,43 (N) vs 19,49 (FW)  $P=.253$ ) [Fig. 3].

As far as the T2w TSE sequence, the basal ganglia SNR and CNR values showed similar and comparable results between the two cohorts of patients (average CNR 63,24 (N) vs 29,03(FW)  $P=.137$ ; average SNR\_SGM 58,41 (N) vs 49,30 (FW)  $P=.081$ ), while the white matter SNR values were slightly inferior in the Feed and Wrap scans (average SNR\_SWM 89,94 (N) vs 66,06 (FW)  $P=.012$ ). [Fig. 4].

Additionally, the white matter and basal ganglia SNR measurements in the T1w SE sequence showed statistically significant differences between the Feed and Wrap MRI images and those of the population performed under sedation (average SNR\_SGM 96,40 (N) vs 76,38 (FW)  $P=.05$ ; average SNR\_SWM 78,58 (N) vs 60,47 (FW)  $P=.034$ ), while the CNR values of T1w SE images were comparable (average CNR 27,20 (N) vs 24,28 (FW)  $P=.418$ ). [Fig. 5].

The qualitative analysis showed that 80% of the F&W scans provided either complete or partially clinically useful information against a predictable diagnostic effectiveness of 99.3% of MRI scans during sedation. Only 20% of the F&W scans were repeated under sedation due to the motion artifacts; the remaining 1% was lost to follow up.

The mean score for diagnostic image quality in T1w was  $4,04 \pm 1,3$  ( $n = 49$ ) in F&W population and  $4,82 \pm 0,53$  ( $n = 146$ ) with sedation, in T2w was  $3,85 \pm 1,35$  ( $n = 53$ ) and  $4,89 \pm 0,57$  ( $n = 153$ ) respectively, in 3D-T1 is  $3,56 \pm 1,56$  ( $n = 45$ ) and  $4,86 \pm 0,56$  ( $n = 152$ ), in DWI was  $4,61 \pm 0,7$  ( $n = 51$ ) and  $4,91 \pm 0,35$  ( $n = 152$ ).

The mean score for motion artifact quality in T1w was  $1,53 \pm 0,87$  ( $n = 49$ ) in F&W population and  $1,06 \pm 0,27$  ( $n = 146$ ) with sedation, in T2w was  $1,53 \pm 0,72$  ( $n = 53$ ) and  $1,08 \pm 0,43$  ( $n = 153$ ) respectively, in 3D-T1 was  $1,83 \pm 0,99$  ( $n = 46$ ) and  $1,05 \pm 0,28$  ( $n = 152$ ), in DWI was  $1,16 \pm 0,37$  ( $n = 51$ ) and  $1,01 \pm 0,11$  ( $n = 152$ ).

The mean score for spatial resolution quality in T1w was  $3,98 \pm 1,35$  ( $n = 49$ ) in F&W population and  $4,81 \pm 0,55$  ( $n = 147$ ) with sedation, in T2w is  $3,92 \pm 1,31$  ( $n = 53$ ) and  $4,90 \pm 0,51$  ( $n = 153$ ) respectively, in 3D-T1 was  $3,56 \pm 1,57$  ( $n = 45$ ) and  $4,84 \pm 0,6$  ( $n = 152$ ).

These differences were significant using the Mann-Whitney U test for image quality, spatial resolution and motion artifact ( $p < 0,001$ ), except for DWI in motion artifact ( $p = 0,008$ ).

Interobserver agreement was only fair to moderate, with kappa values ranging between 0,23 and 0,56.

Age of the infants had no statistical correlation with the scan outcome and the need to repeat imaging.

## DISCUSSION

This study demonstrated that the “feed and wrap” technique can facilitate the execution of brain MRI in pre-term and full-term newborns, from the first days of life up to the fourth month, for the evaluation of suspected neonatal hypoxic-ischemic encephalopathy, without the need of sedation.

One of the earliest studies on this technique, conducted by Sury et al. [14] reported an efficacy rate of 75% for F&W. More recent studies [7, 15] reported a higher success rate.

Antoni et al. and Moltoni et al. showed that 99% of scans provided either complete or partially clinically useful information, with only 11% of cases required repeat imaging. The improvement is probably due to the implementation of standardized protocols performed by trained pediatric teams and advancements in MRI technology. To our knowledge it is the first study that has carried out a quantitative evaluation of the examinations performed with the feed and wrap technique.

Our quantitative analysis showed that DWI and T2w images in the feed and wrap population were comparable to those acquired under sedation in term of CNR and SNR values, in both the white matter and basal ganglia. Furthermore, the CNR values of T1w SE images were also similar between the two groups. On the other hand, all image quality scores were significantly better with sedation ( $p < 0.001$ ), except for DWI, where the difference was marginal.

Despite these differences from qualitative analysis, our study showed that MRI scans obtained using the F&W technique provided either complete or partially clinically useful diagnostic information in most cases.

Consistent with the recent literature, our results highlight how the majority of MRI examinations, even the scans are of suboptimal quality, are considered diagnostic. Indeed, a recent retrospective evaluation of Moltoni et al. [15] showed that, with a feed and wrap technique, only two of the 82 MRI examinations included in the study required a second MRI examination with anesthesia. In a more recent paper, Lollert et al. [16] demonstrated in a large patient cohort throughout a qualitative analysis (scale of 4 point) that the feed and wrap technique is feasible and safe.

In our study, the average score for diagnostic quality of T2w, T1w, and DWI sequences was approximately 4 out of 5 on the Likert scale. These three sequences, particularly DWI, are the most valuable for the early identification of ischemic damage in neonatal HIE.

3D-T1 sequence performed under sedation showed higher contrast-to-noise (CNR) and signal-to-noise (SNR) ratio, and higher overall diagnostic image quality, with statistically significant differences in the white matter and basal ganglia. In our opinion, this sequence particularly benefits from sedation due to its longer acquisition time compared to 2D sequences, its heightened susceptibility to motion artifacts owing to its volumetric nature, and its increased noise levels, which often risk waking the infant despite

the use of ear-covering pads. For the clinical evaluation of HIE, 3D-T1 provides less diagnostic information compared to other sequences. Nevertheless, it remains a critical component of the infants' MRI protocol for assessing morpho-structural alterations and white matter myelination. A potential recommendation for protocol design is to schedule this sequence as the last acquisition, minimizing the risk of infant awakening and subsequent interruption of the MRI examination.

The moderate interobserver agreement (K values between 0.23 and 0.56) suggests variability in how different observers assess image quality. It could reflect the difficulties in interpreting MRI scans of infants by junior neuroradiologist, especially when motion artifacts are present. For this reason, may be appropriate the imaging evaluation by expert neuroradiologist. This data underscores the importance of having expert neuroradiologists evaluate such scans to ensure diagnostic accuracy.

As clinical consideration, when using the F&W technique, prioritizing sequences directly related to the clinical indication (e.g., HIE) is advisable. While F&W is a viable alternative in many circumstances, the higher frequency of motion artifacts and reduced spatial resolution make sedation the gold standard for conditions requiring optimal image quality, such as brain malformations or tumors. Each case should be evaluated individually, with the primary goal of minimizing sedation while addressing the clinical needs. In our study, despite the extremely high rate of success of the MRI scans performed during sedation (93%), however in 1 case out of 155 it was necessary to stop and then repeat the scan since the patient suffered a cardiac and respiratory arrest during the procedure. This highlights the potential risks associated with sedation in infants and reinforces the value of exploring sedation-free alternatives wherever possible.

Infants should ideally undergo MRI without sedation, using a combination of feed and swaddle, noise reduction and optimization of sequences to avoid motion. Reduced reliance on sedation not only lowers clinical risks but also improves resource utilization, such as reducing procedural costs.

Our study has several limitations. It was a retrospective single-center study, with an imbalance in cohort sizes, as the sedated group included significantly more patients than the F&W group. Additionally, the strict selection criteria limited the inclusion of older infants, which may influence the generalizability of our findings.

## CONCLUSION

The diagnostic quality of MRI images acquired under sedation was found to be superior to that of images acquired with the "feed and wrap" technique; however, the latter technique can ensure good quality brain images in newborns and can be used effectively to detect diagnostic features of HIE. It should be emphasized that the "feed and wrap" technique is not burdened with adverse events and can be repeated in case of early awakening of the infant.

## Declarations

# CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

## Author Contribution

All authors contributed to the study conception and design, reviewed the manuscript and approved the final manuscript. C.S. F.L. and SG wrote the main manuscript. C.S., F.L., G.V., L.G., A.P., T.V., R.R., M.M., performed material preparation, data collection and analysis. G.V. and A.I. did performed analysis and prepared Figures and tables.

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## Tables

Table 1. Infant imaging protocol with suggested MRI sequence parameters.

| Sequence      | TE (ms) | TR (ms)  | Slice thickness (mm) | Matrix  | FOV (mm) | Other         |
|---------------|---------|----------|----------------------|---------|----------|---------------|
| T1 SE ax      | 15      | 800      | 3                    | 212x180 | 180x130  | Flip angle 90 |
| T2 TSE ax     | 140     | 10000    | 3                    | 276x272 | 180x130  | Flip angle 90 |
| T2 TSE cor    | 140     | 10000    | 3                    | 276x268 | 180x130  | Flip angle 90 |
| DWI           | 90      | shortest | 3                    | 100x98  | 180x180  | b-value 1000  |
| SWI           | 12      | shortest | 2                    | 232x168 | 210x178  | Flip angle 20 |
| 3D-T1 TFE sag | 4.6     | shortest | 1                    | 172x137 | 172x136  | Flip angle 10 |

Table 2. Qualitative image assessment criteria. Diagnostic quality and spatial resolution were assessed using a 5-point Likert scale, ranging from 1 (non-diagnostic) to 5 (excellent). Motion artifacts were assessed using a 3-point Likert scale, ranging from 1 (not relevant) to 3 (non-diagnostic).

| Score | Diagnostic Quality   | Spatial resolution   | Motion Artifact         |
|-------|----------------------|----------------------|-------------------------|
|       | 5-point Likert scale | 5-point Likert scale | 3-point Likert scale    |
| 1     | non-diagnostic       | non-diagnostic       | not relevant            |
| 2     | poor                 | poor                 | relevant but diagnostic |
| 3     | moderate             | moderate             | non diagnostic          |
| 4     | good                 | good                 |                         |
| 5     | excellent            | excellent            |                         |

## Figures

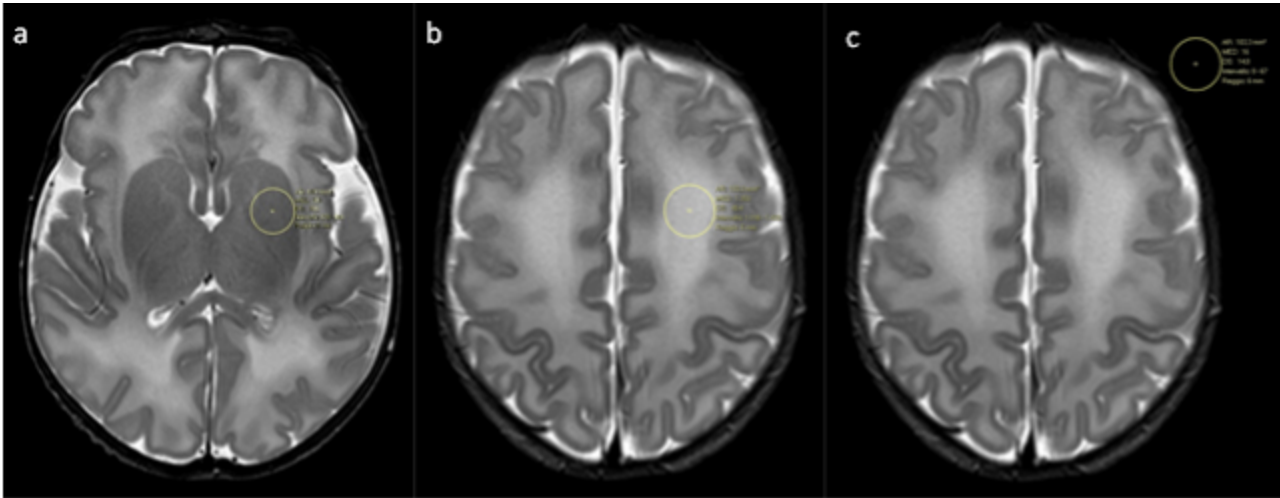


Figure 1

Axial T2-weighted MR images showing examples of regions of interest (ROIs) positioned in the basal ganglia (a), centrum semiovale (b), and outside the head (c).

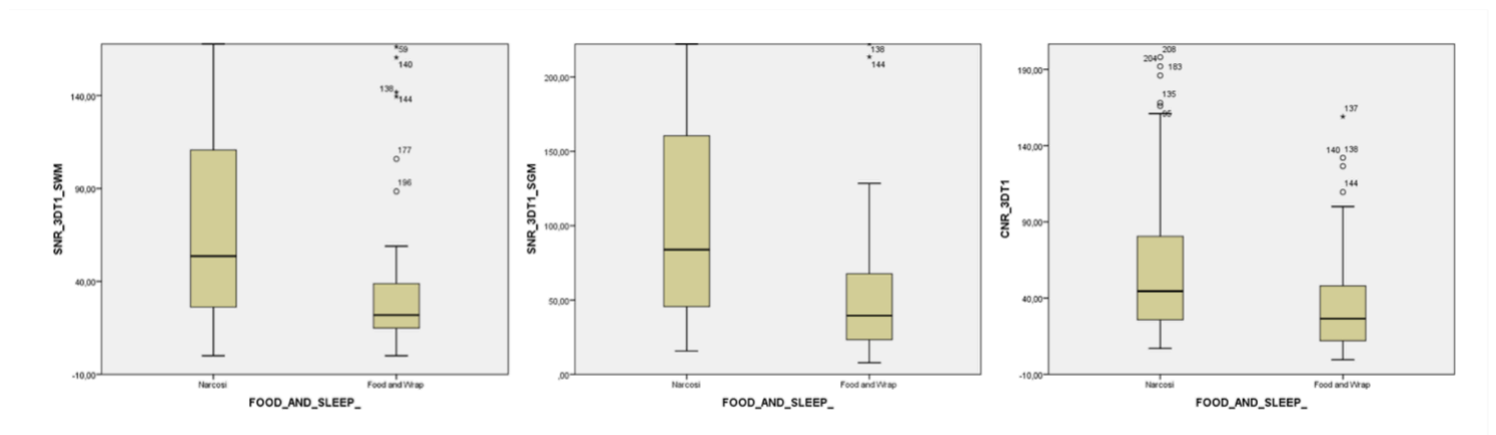


Figure 2

Box plot representation of SNR and CNR values measured on 3D-T1 sequence images acquired during Feed and Wrap MRI, and under anesthesia. Boxes indicate the interquartile range, horizontal lines represent the median values, whiskers indicate minimum and maximum values, and individual points represent outliers.

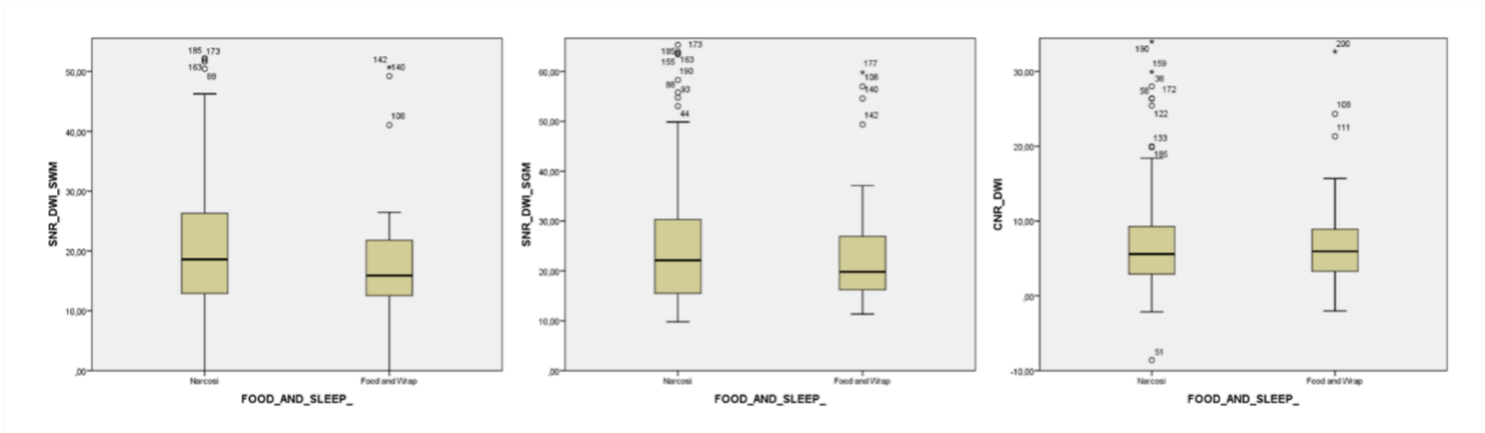


Figure 3

SNR and CNR values obtained from DWI sequence images acquired in Feed and Wrap MRI, and under anesthesia conditions.

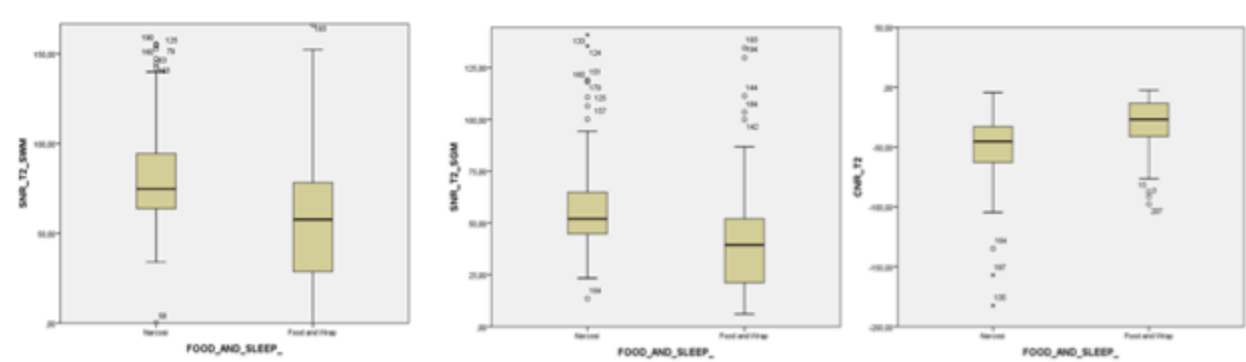


Figure 4

Assessment of SNR and CNR values calculated from T2 TSE sequence images in Feed and Wrap MRI, nad anesthesia acquisitions.

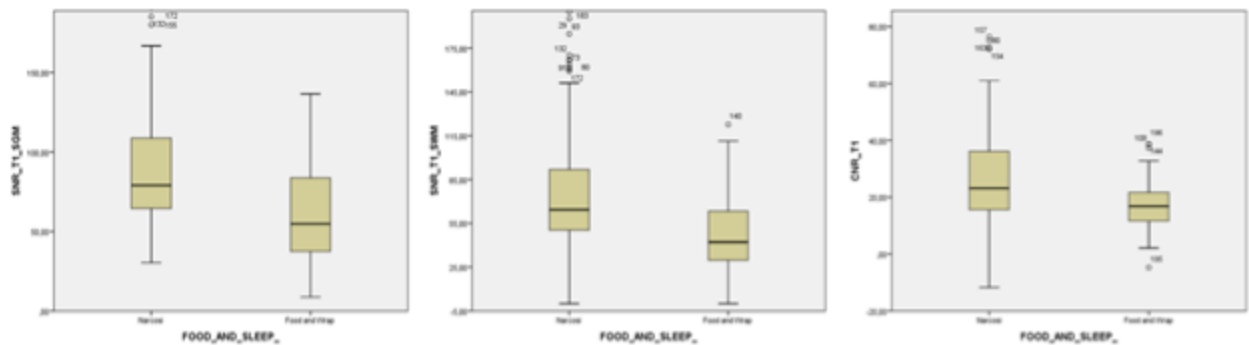


**Figure 5**

Quantitative evaluation of SNR and CNR values measured on T1 SE sequence images obtained during Feed and Wrap MRI, and under anesthesia conditions.