

Chapter 2

The Role of MRI in GERD

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2.1 Summary

The current diagnosis of GERD is based on a combination of endoscopy, pH monitoring, manometry, and imaging tools, such as a barium study [1]. The most sensitive technique for the assessment of gastroesophageal reflux is 24-h pH monitoring [2, 3], as well as manometry to evaluate esophageal motor disorders and functional disorders of the gastro-esophageal sphincter [4–6]. Catheters and probes for these examinations are uncomfortable, time-consuming, and not generally available.

Endoscopy is capable of detecting advanced esophagitis, but lacks sensitivity in determining pathological reflux, which is a particular limitation, as many patients with GERD do not display macroscopic erosions [7] at endoscopy.

Barium studies allow the visualization of esophageal and gastro-esophageal morphology and the alterations during physiological events with good specificity, but with a sensitivity of about 40% [8] and significant amounts of ionizing radiation [9].

With the introduction of ultrafast MR sequences with increasing temporal resolution to the subsecond level, dynamic MR fluoroscopy has become a reality for the assessment of morphological and functional imaging of the esophagus [10–13]. MRI swallowing is a completely non-invasive procedure, without ionizing radiation. Therefore, it can be implemented in pediatric patients [14] and pregnant women without danger, as an initial examination or as a follow-up examination after therapy, i.e., after anti-reflux surgery [15]. At present, MR fluoroscopy has been effectively used in oropharyngeal imaging [9, 12] and for the assessment of esophageal motility disorders, GERD [13, 16], as well as for post-surgery patients after narrow gastric tube reconstruction in esophagectomy [17].

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Recent advances in magnetic resonance imaging (MRI) have led to the development of a fast and accurate technique for monitoring the dynamics of the physiological processes of the gastroesophageal region in real-time, as well as evaluating surrounding structures. Due to the short examination protocol, it can be easily integrated into the clinical routine.

2.2 Impact of MRI in Diagnosing GERD

Gastroesophageal reflux disease (GERD) occurs when the reflux of gastric content into the esophagus provokes mucosal injury, often combined with typical symptoms like heartburn, acid regurgitation, globus sensation, or dysphagia due to an ineffective antireflux barrier between the esophagus and the stomach [18]. The pathophysiology of GERD is multifactorial and overlaps with other functional disorders of the esophagus and stomach, such as esophageal motility disorders [19]. To diagnose GERD, many invasive and non-invasive techniques, such as endoscopy, manometry, 24-h-pH monitoring, impedance measurements, and barium esophagram, are available. Each of these methods covers only a part of some aspect of this disease and a standardized diagnostic procedure has not yet been established.

Videofluoroscopy or barium swallow are the most common radiographic methods, which allow an assessment of the morphology and functionality of the esophagus and the GEJ. However, these techniques cannot display surrounding structures, and requires ionizing radiation exposure. Due to the radiation exposure, a short examination time is required and the procedure cannot be repeated arbitrarily.

The beneficial aspects of MRI include excellent soft-tissue contrast without exposure to ionizing radiation. Study results [7, 10, 11, 13, 14, 16, 20] have demonstrated the feasibility of dynamic swallowing MRI in healthy volunteers [20], the assessment of esophageal motility [13, 14], as well as the evaluation of bolus transit and reflux events [14] in patients with GERD.

Compared to videofluoroscopy, MRI swallowing offers the possibility of multi-planar imaging in every desired plane. Thus, an exact measurement of the size of a hiatal hernia, which is strongly associated with GERD [5, 6], is possible in various views (Fig. 2.1) [14]. The size of the hernia shows a strong correlation with the grade of reflux [14]. Approximately 60–80% of patients with reflux esophagitis have a hiatal hernia, whereas only 3–7% of patients without a hiatal hernia show signs of reflux esophagitis [5, 6, 21, 22]. The clinical importance of the size of a hiatal hernia was described by Jones et al. [23] as well. An increased hernia size is significantly correlated with total esophageal acid exposure, acid clearance time, and esophagitis severity [23]. A correlation between the prevalence of Barrett's esophagus and the size of a hiatal hernia has also been reported by [24], as well as the increased risk of esophageal cancer [25] in patients with hiatal hernia.

Dynamic MR imaging of reflux events requires an image plane that should be oriented through the GEJ. Thus, sagittal and coronal double-oblique angulated planes are preferred [14]. An axial orientation is favored for the detection and measurement of an axial hiatal hernia (Fig. 2.2).

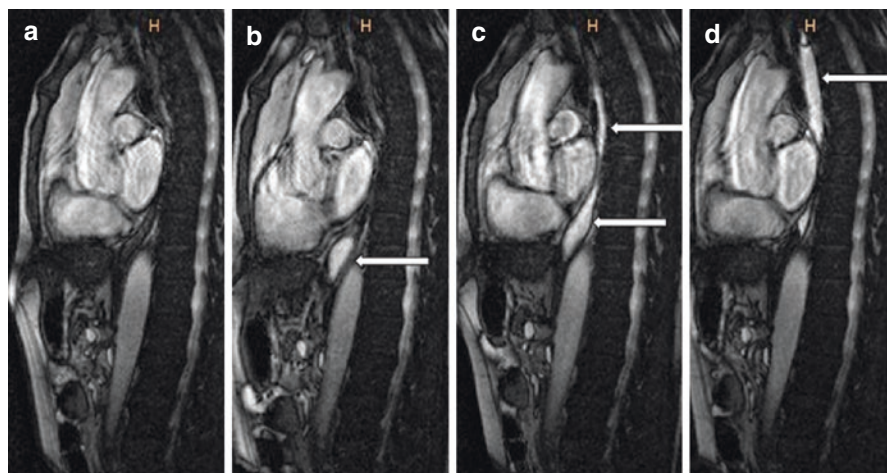


Fig. 2.1 Dynamic FFE pulse sequence in the sagittal view shows spontaneous gastroesophageal reflux (*arrows*) with typical caudo-cranial propagation of the bolus (**a–d**)

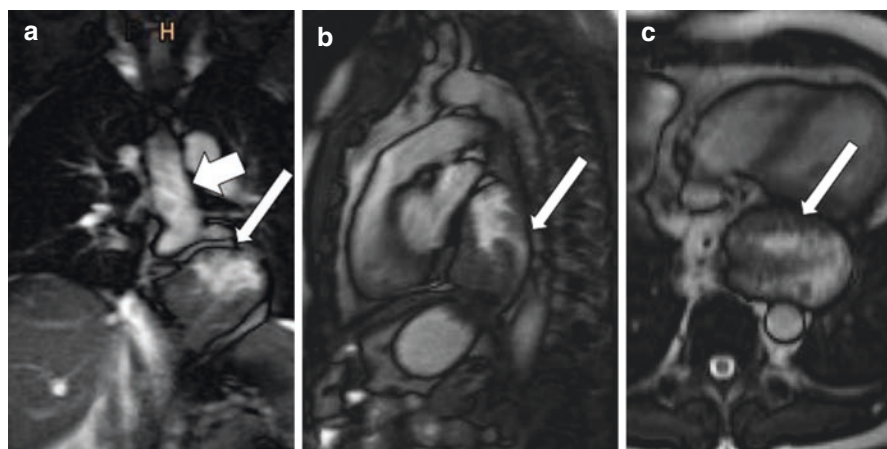


Fig. 2.2 Dynamic B-FFE pulse sequence shows a fixed axial hernia filled with buttermilk-gadolinium (*arrows*) in the coronal (**a**), sagittal (**b**), and axial views (**c**). A spontaneous gastroesophageal reflux from the hiatal hernia is demonstrated (*thick arrow*)

These orientations, in combination with the use of three contiguous slices for better coverage of the entire esophagus, which is the main challenge in this examination, promise a good correlation between reflux events in MRI and pathologic DeMeester score in pH-metric studies [14]. Another publication did not report any correlation between reflux events in MRI and grade of reflux with endoscopic findings and Carlson's questionnaire score [16]. Gastroesophageal reflux, detected on MRI, correlated to a DeMeester score >14.7 , which is indicative of gastroesophageal reflux, was diagnosed in 11 of 12 patients in a study by Zhnag et al. [7]. When comparing functional parameters between healthy volunteers and patients,

statistically significant differences between healthy volunteers and patients could be evaluated based on diaphragm-to-sphincter distance, sphincter length, and sphincter transit time [7]. There was no significant difference of the HIS angle between healthy volunteers and patients, which is contrary to the longstanding hypothesis that a smaller HIS angle forms an anatomical antireflux barrier by a flap valve mechanism [26, 27].

The use of a simple and quick MR protocol, in combination with a good visible contrast medium, is mandatory to integrate this examination into the clinical routine.

The MRI is usually performed in the supine position on a 1.5 T or 3 T MRI, provided the patient is not at risk of aspiration. A body phased-array coil should be placed upon the chest. After a reference scan, a coronal T2-weighted, single-shot Turbo-Spin-Echo-sequence (TSE) or a T2-weighted half-Fourier-acquired, single-shot turbo spin echo (HASTE) sequence for orientation of the course of the esophagus and the gastro-esophageal junction (GEJ) should be performed. Then, a sagittal and an axial plane are obtained. After the “anatomical” static T2-weighted sequences, a sagittal, oblique B-FFE (Balanced Fast Field Echo Sequence) or TrueFisp sequence (True Fast Imaging with steady state precession) with three contiguous slices is centered on the lower esophagus in the coronal view of the T2-weighted image according to these sequence parameters (Fig. 2.3). An additional coronal plane then is planned in the sagittal view. During these dynamic series, a buttermilk-gadolinium mixture (Dotarem®, gadoterate meglumine, Guerbet, Germany) at a dilution of 40:1 is placed in a cup with a long plastic tube in the MR gantry. The other end of the plastic tube is placed into the patient’s mouth. Patients then are instructed to take a bolus in their mouth and swallow in a single gulp to prevent repetitive swallowing. If the coverage of the esophagus and the GEJ is inadequate, the pulse sequence is repeated in a slightly different angulation. Since there is increased awareness of the possible side effects of gadolinium or possible interaction between gadolinium and

Tabelle 1. MR Sequence parameter		
Parameter	HASTE	B-FFE
Repetition time (ms)	1800	2.9
Echo time (ms)	100	1.5
Flip angle °	150	60
Acquisition matrix	256x256	256x256
Field of view (mm)	350x350	375x375
Slice thickness (mm)	5	15
Intersection gap (mm)	–	0.4
Aquisition time (s/image)	1	1
Aquisition cycle (s)	–	60
Slice orientation	1. Coronal	1. Sagittal oblique
	2. Sagittal	2. Coronal oblique
	3. Axial	3. Axial

Fig. 2.3 Sequence parameter our routinely used MRI protocol

gastric acid, which has not, as yet, been verified, we have changed the oral contrast medium to Lumivision® (Bender Group, b.e. imaging, Baden-Baden, Germany). Lumivision® is a natural liquid contrast for oral application in MRI and contains different special fruit juices like pineapple, agave, and black currant. Patients with a hypersensitivity to these fruits, as well as patients with fructose malabsorption, should avoid taking this contrast medium. Diabetic patients must adjust their medication according to the sugar content (6.5BE per bottle of 250 ml Lumivision®).

Real-time MRI offers a new perspective for a robust anatomic visualization combined with functional assessment of gastroesophageal reflux in patients. Another advantage is the possibility to directly view the surrounding structures, which is not possible with conventional examination techniques, for example, and represents a reliable tool with which to identify extraluminal findings. As a consequence, this non-invasive and non-ionizing approach has already shown great promise for the characterization of complex motions during swallowing, which could be of particular interest in pregnant and young patients. This method cannot replace ph-metry and manometry as measurable tools for the identification of reflux events and motility problems, but it could be a worthwhile method in pregnant patients, children, and other patients in whom a ph-metric/manometric tube cannot be placed.

2.3 The Role of MRI in Patients After Fundoplication

After a fundoplication procedure, radiologic work-up plays an important role in identifying possible problems.

The impact of a routinely conducted postoperative swallowing examination has been discussed controversially [28]. However, 2–17% of patients need a postoperative diagnostic clarification of their new or recurrent clinical symptoms, such as recurrent heartburn, regurgitation, or dysphagia. During the last several decades, a wide range of diagnostic modalities, such as endoscopy, pH monitoring, manometry, and barium swallow, were used to solve the possible problems. However, the modalities cover only a partial aspect of potential postoperative failure and are inaccurate in up to 40% of cases [29] in explaining the reason for dysphagia.

Because these patients are often young, a functional and morphologic imaging method without ionizing radiation was introduced in [15]. This study analyzed the role of MRI for the evaluation of anatomical and functional disorders after Nissen fundoplication compared to intraoperative findings in 29 patients. MRI was able to determine the position of the fundoplication wrap in 93% (Fig. 2.4), and correctly identified 67% of all malpositions of the wrap. Intrathoracic migration of the wrap, in particular, can be detected very well (Fig. 2.5). All wrap disruptions (Fig. 2.6), as well as all stenosis could be identify by MRI. In three cases, stenosis were caused by too-tight crural sutures, and, in two cases, by too-tight wraps. Stenosis that are shorter than 1 cm in length are usually caused by too-tight crural sutures. A stenosis measuring 2–3 cm in length is usually caused by a too-tight (Fig. 2.7) or too-long wrap (>3 cm).

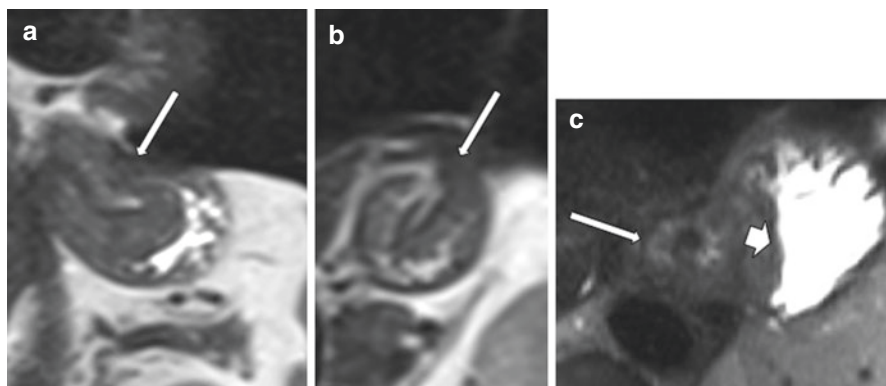


Fig. 2.4 Normal postoperative appearance after Nissen fundoplication on MRI. The coronal (a) and sagittal (b) view shows the correct position of the wrap under the diaphragm. A ring-like “pseudotumor” (long arrow) of the fundoplication, and a well-defined smooth defect in the fundus (short arrow) acquired in the axial plane (c)

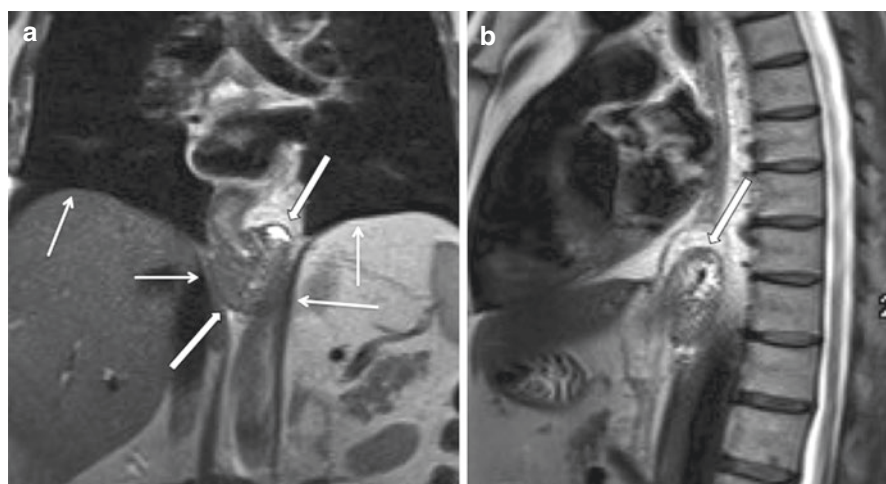


Fig. 2.5 Intrathoracic wrap migration. T2w HASTE sequences in the coronal view were performed to demonstrate the integrity of the wrap (long arrow) (a), but the wrap was detected above the esophageal hiatus and above the diaphragms (thin arrows) (b)

When abnormal esophageal motility is present before surgery, there is a greater likelihood of dysphagia developing after fundoplication [30]. The prolonged mechanical obstruction of the distal esophagus by the fundoplication wrap, with loss of peristalsis above the wrap, could be the cause of so-called secondary achalasia, even if there was normal esophageal motility before surgery.

Thus, the examination of peristalsis and esophageal motility in patients with dysphagia after Nissen fundoplication is mandatory. Usually, this condition is observed

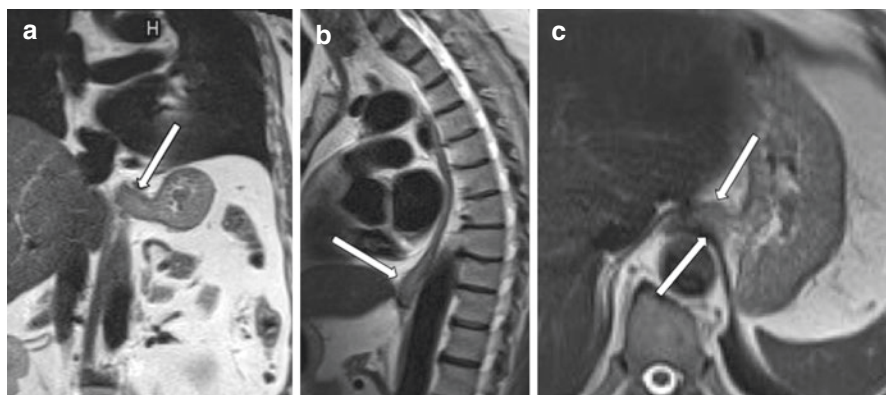


Fig. 2.6 Complete wrap disruption. Complete wrap disruption obtained in a patient with symptoms of recurrent reflux. The typical “pseudotumor” is missed on the coronal, sagittal and axial (*arrows*) view (**a–c**)

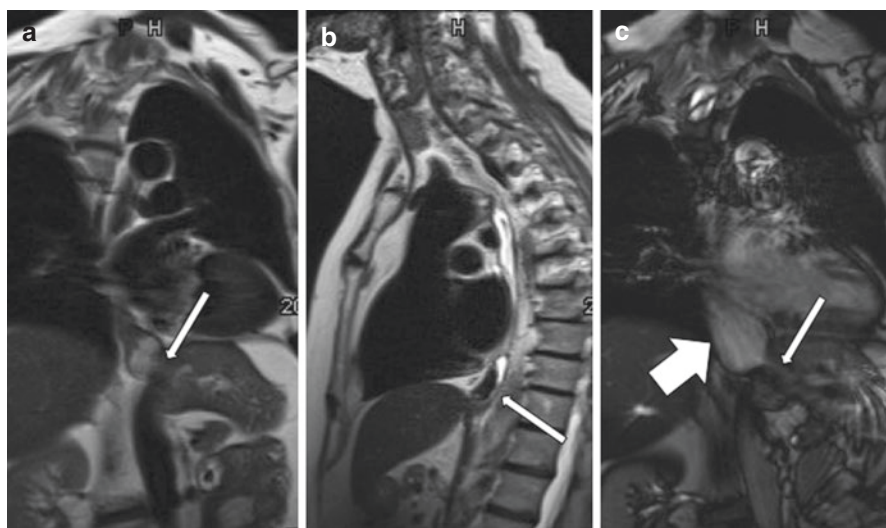


Fig. 2.7 Stenosis at the gastroesophageal junction. If the stenosis measures less than 1 cm in length (*thin arrow*) on the coronal and *sagittal* view, it strongly suggests too-tight crural sutures as the cause of dysphagia (**a, b**). A ballooning of the distal esophagus can be shown in the *coronal* view of the dynamic FFE pulse sequence (*thick arrow*) (**c**)

by manometry and barium swallow, the latter of which has the disadvantage of ionizing radiation. A delayed bolus transit of more than 20 s and a lack of propulsive peristalsis was found in MRI swallowing in our study in three patients. The diagnosis of secondary motility disorder was confirmed by manometry. Another study by Covotta et al. showed a sensitivity of 87.5%, with a specificity of 100% in MRI,

compared to manometry, for the detection of motility alterations in 24 patients who presented with dysphagia and specific and non-specific motor disorders [31]. There is a lack of other MRI studies after esophago-gastric operations, except for one study by Panebianco et al. This paper evaluated the functionality and morphology of a neo-esophagus with narrow gastric tube reconstruction (NGT) after radical esophagectomy [17] using MRI. MRI was able to properly investigate the peculiar alterations that developed after this kind of intervention [17]. These authors showed the strong association between an increased NGT caliber and poor NGT functionality.

A short examination protocol in symptomatic patients after antireflux surgery should include HASTE sequences for clarifying the wrap situation and dynamic sequences for excluding a secondary motility disorder:

Starting with a single-shot sequence, such as a T2-weighted half-Fourier-acquired single-shot turbo spin echo (HASTE) sequence, a good overview of the postoperative hiatal anatomic situation can be obtained. The HASTE sequence is first performed in the coronal, then in the sagittal and axial views.

This sequence serves to depict the wrap, its exact location, and any possible slipping. A slipping or telescope phenomenon indicates that a part of the stomach slips through the wrap into the thoracic area.

The HASTE sequence in the coronal and sagittal views can also depict the complete course of the esophagus. The best views for depicting the position of the fundoplication wrap are the coronal and sagittal views. The axial view is preferred for estimating the integrity of the wrap with a typical “ring-like pseudotumor” appearance (Fig. 2.4c), as well as for evaluating a possible recurrent hernia.

The HASTE sequence is very helpful in depicting the correct position for the dynamic double-angulated B-FFE or TrueFisp sequences, which is performed next. A sagittal, oblique B-FFE sequence is performed as a pulse sequence with three contiguous slices for better coverage of the entire esophagus, and is centered on the lower esophagus.

This dynamic sequence, in particular, enables an evaluation of peristalsis and the bolus transit time of the esophagus, including the lower esophageal sphincter. In most patients, it is also possible to assess the passage through the fundoplication wrap, even though this occurrence often can be evaluated better with a coronal view, which is performed after the sagittal view. The coronal view should be centered on the course of the lower esophagus and the wrap. A dynamic axial view has no advantages and is rarely executed in routine clinical practice.

With the introduction of dynamic MRI in symptomatic patients after fundoplication, it is now possible to visualize not only luminal structures, such as with a barium esophagogram, but also to illustrate structural details of the esophagus and stomach, as well as the surrounding structures. Thus, rupture or malposition of the fundoplication wrap, as well as other anatomical problems in the hiatal position, can also be detected, as well as motility disorders. The short examination protocol of about 30 min provides the possibility to include this examination into normal clinical routine.

2.4 Summary

Swallowing MRI is coming of age. Until now several publications of swallowing MRI in healthy patients, as well as in patients with GERD and in symptomatic after antireflux surgery could give novel insights into this disease without ionizing radiation. Not only luminal structures but also anatomical as well as functional structures in one diagnostic method can now be identified.

The development of more uniformed analysis methods in future will aid translation into clinical routine. Therefore further work validating this method is needed.

What Is the Current Knowledge and What Future Direction Is Required

1. With the introduction of ultrafast MR sequences with increasing temporal resolution, dynamic MR swallowing has become reality for the assessment of morphological and functional imaging of the esophagus.
2. MRI swallowing is a completely non-invasive procedure, without ionizing radiation.

Due to the short examination protocol, it can be easily integrated into the clinical routine.

3. The beneficial aspects of MRI include excellent soft-tissue contrast and the possibility to directly view the surrounding structures, which is not possible with conventional examination techniques, for example, and represents a reliable tool with which to identify extraluminal findings.
4. MR swallowing cannot replace ph-metry and manometry as measurable tools for the identification of reflux events and motility problems, but it could be a worthwhile method in patients in whom a ph-metric/manometric tube cannot be placed.
5. After antireflux surgery a rupture or malposition of the fundoplication wrap, as well as other anatomical problems in the hiatal position, can also be detected, as well as secondary motility disorders.
6. The implementation of uniformed analysis methods and scoring systems are needed to translate MR swallowing into clinical routine.

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