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ARTICLE TITLE

Esophagus and stomach: is there a role for MRI?

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KEY POINTS

MRI can be included in the diagnostic pathway of a wide range of benign and malignant conditions of the esophagus and the stomach.

An adequate MRI protocol is crucial for the assessment of the esophagus and stomach. This includes high-resolution multiplanar T2-weighted, diffusion-weighted and dynamic contrast enhanced imaging.

Different quantitative imaging biomarkers from DWI and DCE hold promise in the evaluation of the aggressiveness, treatment response and prognosis of esophageal and gastric cancer.

There remains a need for improvement and standardization before MRI becomes an accepted and widely adopted method to investigate the gastro-esophageal tract.

SYNOPSIS

MRI has been increasingly used in the diagnostic work-up of benign and malignant conditions of the gastro-esophageal tract. The use of an adequate MRI protocol is crucial and includes high-resolution multiplanar T2-weighted turbo spin echo sequences for the high soft tissue contrast resolution (i.e. detailed anatomic evaluation) together with DWI and DCE imaging, which give also the possibility to investigate the tissue at a cellular level by means of quantitative imaging.

Introduction

A wide range of esophageal and gastric conditions (both benign and malignant) can be investigated with barium contrast studies for the evaluation of mucosal surface lesions but such techniques provide little information about the extramucosal extent of disease.

Other imaging modalities such as endoscopic ultrasound (EUS), computed tomography (CT) and 18F-fluorodeoxyglucose positron emission tomography (18F-FDG-PET) permit the assessment of wall thickness, mediastinal involvement, adjacent lymphadenopathy, and distant spread.

Over the last twenty years, magnetic resonance imaging (MRI) has been increasingly used as a valid diagnostic tool in adjunct to these imaging techniques.

In this article, we will provide the reader with some of the most common MRI findings in the gastro-esophageal tract and discuss the goals for a widespread application of this technique at this regard.

MRI technique

MRI is performed with either a 1.5T or 3T system, using an external surface coil (i.e. multiple channel phased array cardiac coil) with cardiac and respiratory triggering.

MRI of the esophagus does not require any specific preparation apart from the administration of intramuscular scopolamine (in the absence of contraindications), especially when the gastro-esophageal junction is the anatomical region of interest.

Differently from the esophagus, MRI of the stomach requires accurate patient preparation: in particular, proper visceral distension is fundamental in order to depict the multi-layer pattern of the gastric wall. After a six-hour fasting, distension is obtained by oral administration of at least 500 ml of water immediately before examination and an intramuscular injection of scopolamine is usually administered in order to decrease bowel peristalsis. [1–4] Some Authors suggest the use of or effervescent granules to obtain gastric distension but in our experience it is not generally used, due to the risk to increase air artifacts from gastric lumen. [1–4]

When water is used as oral contrast agent, the patient is scanned in the prone or supine position dependent upon the location of the region of interest to allow proper contact between the oral contrast medium and the visceral wall. The positions should be reversed when effervescent

granules are used. [1]

Although standardized MRI protocols for both organs have yet to be reported, as a rule of thumb the examination should include:

- High-resolution multi-planar T2-weighted imaging (T2-WI), including turbo spin echo sequences with and without fat-suppression with cardiac and respiratory gating

T2-WI is crucial for the anatomy of the organ, as it allows excellent soft-tissue contrast together with good spatial resolution and a high signal-to-noise ratio.

- Axial diffusion-weighted imaging (DWI) with different *b*-values (usually up to 1000 s/mm^2)

DWI provides information about the tissue structure and cellular density as it reflects the mobility of water protons measuring the apparent diffusion coefficient (ADC). This quantitative index is considered a promising imaging biomarker both for the esophagus and the stomach[5,6].

- Axial breath-hold T1 weighted sequences with fat suppression, acquired before and after intravenous injection of contrast agent

Dynamic contrast enhanced (DCE) MR imaging involves the acquisition of serial T1-weighted images before and after injection of a bolus of chelated gadolinium molecule. The application of DCE-MRI in oncology has been

growing over the last few years thanks to the continuous technical developments. Moreover, different quantitative biomarkers extrapolated from DCE-MRI maps according to the Tofts model have been investigated in the gastro-esophageal tract. [7]

Table 1 and Table 2 list the two protocols for MRI of the esophagus and the stomach, respectively. As far as the esophagus is concerned, the study should commence with a sagittal high-resolution T2-weighted acquisition so as to orientate the axial images perpendicular to the long axis of the organ. A coronal acquisition should be also added in the protocol if the region of interest is the gastro-esophageal junction, as this allows to clearly delineate the diaphragmatic hiatus. [6,8]

MR imaging anatomy

Esophagus

The esophagus is a muscular tube (20-25 cm in length) that connects the pharynx to the stomach and is composed of three segments: cervical, thoracic, and abdominal.

Histologically, it is composed of different layers:

- the inner layer (i.e. stratified squamous epithelium that changes abruptly at the cardia of the stomach into simple columnar epithelium)
- the muscularis mucosae
- the submucosa
- the inner circular muscular layer
- the outer longitudinal muscular layer

There is no serosal layer and the thickness of the esophageal wall is usually considered physiological up to 5 mm.

On T1-weighted imaging, the esophagus appears as a structure of low-signal intensity, contrasted by the high-signal intensity of the surrounding fat. The esophageal layers are clearly visible on high-resolution T2-WI MRI. On an axial T2-WI acquisition, this is characterized by a three-

layered pattern whose distinction is mainly based on the higher signal intensity of the middle layer (Fig. 1) [8,9]:

- Mucosa (inner layer): intermediate/low signal-intensity
- Submucosa: high-signal-intensity submucosa
- Muscularis propria (outer layer): low-signal-intensity

There is also evidence of ex-vivo studies conducted at 7T demonstrating up to eight layers of the esophageal wall on ultra-high-resolution T2-weighted sequences. [10]

Stomach

The gastric wall consists of the following five layers:

- Mucosa (inner layer)
- Submucosa
- Muscularis propria
- Subserosa
- Serosa (outer layer)

However, on T2-WI acquired at 1.5T, the gastric wall is generally depicted as a three-layer structure, as the muscularis propria, the subserosa and the serosa are not clearly distinguishable [11]:

- Mucosa: low signal intensity

- Submucosa: intermediate to high-signal intensity
- Outer layer: low-signal intensity corresponding to the muscularis propria, the subserosa and the serosa

After intravenous administration of a contrast agent, the normal gastric wall demonstrates a two-layer pattern, corresponding to the inner mucosal layer (early enhancement) and the outer submucosal and muscular layers (delayed enhancement) [12]. (Fig. 2)

As for the esophagus, there are experimental studies on ex vivo specimens with variable magnetic fields demonstrating up to seven gastric wall layers on T2-WI. [13–15]

MRI of the most common benign findings

In this section, we review the clinical characteristics and MR appearances of the most common esophageal and gastric benign findings, with emphasis on the MRI features.

Esophagus

- Esophageal diverticulum

Esophageal diverticula may be formed either by pulsion (i.e. increased intraluminal pressure against a weak esophageal wall, more common in the cervical or distal segments) or by traction (e.g. scarring, fibrosis or inflammation in periesophageal tissue, more common in the middle segment). Pulsion diverticula consist only of mucosa (false diverticula) while traction diverticula contain all esophageal layers (true diverticula), including muscular layers, and therefore they tend to empty when the esophagus collapses.

According to their location, the most common pulsion diverticula occur at the pharyngoesophageal junction (e.g. Zenker's diverticulum, which is a pulsion diverticulum) (Fig. 3) and above the esophageal hiatus (e.g. epiphrenic diverticulum).

- Esophageal leiomyoma

Leiomyomas are the most common mesenchymal tumors of the esophagus and they can be associated with Alport syndrome. [16] They arise from the smooth muscle layers (usually the muscularis propria) and are mostly found in the middle and distal third of the esophagus (where the content of smooth muscle is greater). They usually range from 2 to 6 cm in diameter and symptoms include dysphagia, vomiting and weight loss. [17]

On MRI, leiomyomas appear as round/ovoid masses with smooth margins, and the surrounding fat is usually preserved. On T1-WI leyomiomas are usually hyperintense while on T2-WI they return hypo- to isointense signal on T2-WI (with respect to the normal esophageal wall) and homogenous enhancement after administration of contrast medium (Fig. 4). [16,18]

However, CT has a higher sensitivity than MRI for the detection of esophageal leyomiomas, as it is possible to depict the characteristic intratumoral 'pop-corn like' calcifications. Surgical resection is the only curative treatment. [19]

- Duplication Cyst

Esophageal duplication cysts occur almost always in the lower third and on the right aspect of the esophagus, and a clear communication with the oesophageal lumen is demonstrated in approximately 20% of cases. [20] On MRI, duplication cysts usually show the common features of cysts (i.e.

hyperintense signal on T2-WI and variable signal intensity on T1-WI depending on the content). (Fig. 5)

Stomach

- Gastric lipoma

Gastric lipomas are rare tumors, accounting for only about 5% of the gastrointestinal tract lipomas and less than 1% of all gastric neoplasms. [21,22]

Lipomas are submucosal, well-defined masses (net margins and broad base) composed of mature adipocytes surrounded by a fibrous capsule. They tend to occur as solitary lesions, usually in the gastric antrum.

CT is the imaging examination of choice for gastric lipomas and even though MRI is as specific as CT in diagnosing gastric lipomas, the use of MRI has been limited [21,22].

MRI is extremely sensitive to fat and can be of help in confirming the adipose nature of the lesion. Therefore, lipomas show high-signal intensity on T1-WI and low-signal intensity on both T1- and T2-WI with fat-suppression, with a clear delineation of the gastric wall.

No enhancement is observed after administration of contrast. (Fig. 6)

- Gastrointestinal stromal tumour (GIST)

Gastrointestinal stromal tumors are mesenchymal tumors that arise in the gastrointestinal tract as well as in extravisceral locations such as the

mesentery, omentum or retroperitoneum. The most common location (70%) is the stomach; 90% of gastric GISTs are benign. [23,24]

Tumor location within the stomach is important for the differential diagnosis: GISTs are often located in the body (75% of cases), whereas leiomyomas and lipomas are almost always seen in the cardia and in the antrum, respectively. GISTs differ from leiomyoimas in that they derive from a precursor of intestinal pacemaker cells (i.e. cells of Cajal) rather than from smooth muscle cells. GISTs may appear as endogastric or exogastric, and they become symptomatic if they enlarge, causing vomiting and ulceration of the lesion (hematemesis, melena and iron-deficiency anemia). [24]k

Small and asymptomatic lesions can be followed up but if they are >2cm they should be surgically removed, as there is an increased risk of malignancy.

On MRI, GISTs are typically hypointense on T1-WI and return intermediate to high-signal intensity on T2-WI with respect to the normal gastric wall, and this feature should be considered pathognomonic of GIST. (Fig 7)

As far as the enhancement pattern is concerned, small GISTs (<5 cm) show homogeneous and persistent enhancement after administration of contrast medium, whereas larger tumors (>5 cm) demonstrate heterogeneous enhancement associated with cystic changes, necrosis and ulceration. Multiplanar acquisitions are crucial to assess the anatomical relationships of GISTs with other organs. There is evidence that DWI is

related to degree of malignancy for GISTs, as ADC values are negatively correlated with the biological aggressiveness of GISTs.

MRI for malignant conditions

Imaging may be helpful for detection, diagnosis, staging, and treatment planning of esophageal and gastric neoplasms.

Esophagus

- Esophageal cancer

Esophageal cancer is the ninth most common type of cancer and the sixth most leading cause of cancer related death. [25]

The two major histological subtypes are squamous cell carcinoma and adenocarcinoma. Early-stage disease can be treated with immediate surgery, while patients with locally advanced cancer usually benefit from radiotherapy and chemotherapy. Therefore, accurate staging is crucial to choose the optimal treatment strategy and to predict the response to neoadjuvant treatment. Several imaging techniques, including EUS, CT and 18-F-FDG PET, have been investigated in the diagnostic pathway of esophageal cancer. [26] MRI is considered a promising technique thanks to the multiplanar acquisitions and the ability to provide excellent soft-tissue contrast, although motion artefacts and the long acquisition time still represent significant technical challenges. [26,27]

On MRI, esophageal carcinoma returns intermediate signal intensity on T2-WI, but it should be kept in mind that fibrosis after neoadjuvant therapy may produce a similar appearance. Although MRI is not the first choice for staging, it is comparable to CT in determining the resectability, mediastinal invasion, nodal involvement, and presence of distant metastases. [28] (Fig. 8)

There is also growing evidence of the promising role of MRI (especially DWI) in the evaluation of treatment response and prognosis of esophageal cancer. [27,29,30] (Fig. 9)

- Tumor recurrence after surgery

Despite the widespread use of neoadjuvant therapy for locally-advanced disease, tumor recurrence after esophagectomy is still common, with a recurrence rate after curative esophagectomy with lymphadenectomy ranging from 40 to 50%. [31]

Recurrence is generally detected as an intraluminal mass or focal wall thickening at the site of the anastomosis. [32] It has been shown that MRI is superior to CT for the assessment of local recurrence, given its capability to differentiate between neoplastic tissue and fibrotic scar according to the different MR signal intensities and morphologic criteria (i.e. mass effect and loss of fat planes). [32]

On MRI, recurrent disease returns increased signal on T2-WI and avid enhancement after administration of contrast, while fibrosis is characterized by low signal on T2-WI and weak enhancement. (Fig. 10)

Stomach

- Gastric cancer

Gastric cancer is one of the most common malignancies worldwide. [33] Accurate preoperative staging of local invasion and nodal involvement is crucial to determine the most appropriate treatment and prognosis for patients with gastric cancer.

Over the last twenty years, multiple imaging techniques (EUS, CT, PET) have gained importance in the management of gastric cancer by improving the likelihood of a radical tumor resection and overall survival. Traditionally, the role of MRI for gastric cancer has been limited, due to the relatively long acquisition times, high costs and technical challenges because of the presence of peristalsis and respiratory artifacts. [3] However, many technical improvements (i.e. fast imaging and motion compensation techniques combined with the use of anti-peristaltic agents) and also the introduction of DWI have shown the promising role of MRI in the diagnostic pathway of gastric cancer.

As previously mentioned, MRI has a high performance in depicting the different gastric wall layers. As the detectability of gastric cancer is influenced by tumor size and local invasion, MRI is accurate in detecting the overall T-staging, especially when T2-WI, DWI and DCE are combined together. [34]

On MRI, the depth of infiltration according to the 8th Tumor Node Metastasis (TNM) [35] classification is assessed as below:

- T1: enhanced tumor that does not invade (T1a) or invades (T1b) the submucosa
- T2: continuous low-signal intensity band or enhanced cancerous portion in correspondence with the low signal intensity band of the muscularis propria
- T3: enhanced tumour invading the subserosa
- T4
    - T4a: interrupted low-signal intensity band or enhanced cancerous portions penetrating the serosa
    - T4b: extension to the adjacent organs.

Accurate preoperative assessment of nodal involvement in patients with gastric cancer is of great importance for selecting the appropriate treatment strategy. Pathologic lymph nodes have usually a short-axis diameter >6mm and regional lymph node involvement is most frequently evaluated using EUS, CT and/or 18F-FDG PET. There are yet no robust data suggesting the superiority of MRI on the other imaging techniques with regards to preoperative loco-regional staging [5]. (Fig. 11, 12 and 13) However, MRI has been proposed as a valuable technique to predict treatment response and prognosis in selected patients.[36,37] An accurate differentiation between responders and non-responders on MRI could assist the clinicians in tailored therapeutic decision-making, as ineffective neoadjuvant regimens could be potentially harmful. There is evidence of

the promising role of DWI and ADC of the primary tumor with regards to the response to neoadjuvant chemotherapy in gastric cancer. [5] Higher ADC values have been found in responders compared to non-responders after neoadjuvant treatment due to the presence of necrosis after successful treatment (i.e. an increase in water diffusivity and, consequently, in ADC values).[38] (Fig. 14)

Summary

MRI of the gastro-esophageal tract has made huge advances following the technical developments and protocol optimizations that have occurred over the last decade. The new technical developments have facilitated the acquisition of high-quality multiplanar images, as well as permitting tissue characterization by means of DWI and fat suppression techniques.
Despite this, several challenges still lie ahead.
There is an unmet need for standardization of MRI protocols, as the different studies in the gastro-esophageal tract have been performed both on 1.5T or 3T scanners and this makes the comparison of results hard.
The lack of consensus on specific imaging sequence parameters is a great limitation, especially for quantitative image analysis. The use of different *b* values in DWI, for example, affects ADC calculation and therefore comparing the results from different centers and scanners is challenging.
Moreover, there is no consensus on how to calculate and interpret ADC values, due to the diverse approaches for the delineation of the regions of interest and the analysis of different ADC values (minimum, mean or median). Similarly, there is variation for T2-WI (e.g. different echo times) and for DCE imaging, where the variation for image acquisition (e.g. temporal resolution) is even greater.
It follows that comparison of results across studies is difficult, and this underlines the need for a careful review of the quality of MR scanners and

the reproducibility of measurement across centers, with a need to establish adequate MRI standards.

However, while there is still room for improvement especially with regards to staging, evaluation of treatment response and prognosis for esophageal and gastric cancer, the application of MRI in the gastro-esophageal tract has a bright future.

There is also an increasing interest in the application of radiomics in esophageal and gastric cancer. [39] In the future, we can expect to see an increased use of quantitative MRI protocols for esophageal and gastric cancers, including more robust data on ADC and other imaging biomarkers, also from different imaging modalities. [22]

Treatment response assessment might benefit from imaging biomarkers derived from functional MRI and this will certainly lead to more reproducible results and will pave to the way to the application of artificial intelligence for image interpretation.

Moreover, the integration of MRI findings with data from other disciplines such as genomics and pathology can further enhance the potential of MRI in the management of esophageal and gastric diseases.

In conclusion, MRI is a robust imaging technique for the gastrointestinal tract and its role in gastro-esophageal tract is promising. The absence of ionizing radiation is important, especially for patients allergic to iodinated

contrast agents and in cases of multiple follow-up studies (e.g. before, during and after therapy), where results from DWI are very promising. However, results from large, multicentric studies are still needed in order to include the use of MRI of the gastro-esophageal tract in common clinical practice.

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Table 1 – MRI protocol for the esophagus

Parameters	***SS Fat suppressed T_2 weighted***	***T_2 weighted***	***SS EP diffusion weighted****	***Gadolinium contrast enhanced***	**TSE PD-BB**
Plane	Axial and sagittal/coronal	Axial	Axial	Axial	Sagittal
TR (ms)	Shortest	2400	Single heartbeat	Shortest	1600 (2 heartbeat)
TE (ms)	100	80	58	Shortest	10
Slice thickness (mm)	4	4	4	25	6
Slice gap (mm)	1	0.4	1	Over contiguous slice	-
Matrix size (reconstructed)	320	288	336	288	512
Field of view (mm)	365 x 284	300 x 280	365 x 319	365 x 289	350 x 350
Flip angle (degrees)	90°	90°	90°	10°	90°

Acquisition time (s)	14	150**	104**	94	11
Number of slices	35	18	30	65	10

Note – EP = Echo Planar, TR = Repetition Time, TE = Echo Time, SS = Single Shot
*b = 0, 600 sec/mm^2
**Total duration according to the cardiac and respiratory frequency

Table 2 – MRI protocol for the stomach

Parameters	***SS Fat suppressed T_2 weighted***	***T_2 weighted***	***SS EP diffusion weighted****	***Gadolinium contrast enhanced***
Plane	Axial and coronal	Axial	Axial	Axial
TR (ms)	Shortest	2400	Single heartbeat	Shortest
TE (ms)	100	80	58	Shortest
Slice thickness (mm)	4	5	4	25
Slice gap (mm)	1	0.8	1	Over contiguous slice
Matrix size (reconstructed)	336	288	336	288
Field of view (mm)	365 x 284	300 x 280	365 x 319	365 x 289
Flip angle (degrees)	90°	90°	90°	10°
Acquisition time (s)	14	150**	104**	94
Number of slices	35	18	30	65

Note – EP = Echo Planar, TR = Repetition Time, TE = Echo Time, SS = Single Shot
*b = 0, 600 sec/mm^2

**Total duration according to the cardiac and respiratory frequency

Figure 1 – MRI and histology of the normal esophageal wall. Axial T2-weighted (A and B) images, macroscopic (C) and microscopic (D) sections of the resected specimen.

Figure 2 – MRI and histology of the normal gastric wall. Axial T1-weighted (A and B) images after injection of gadolinium, macroscopic (C) and microscopic (D) sections of the resected specimen.

Figure 3- Zenker's diverticulum in a 44-year-old female. (A) Axial T2-weighted and (B) dynamic contrast enhanced images showing left posterolateral outpouching (arrows) of the esophageal mucosa and submucosa proximal to the upper esophageal sphincter.

Figure 4 – Esophageal leiomyoma in a 33-year-old male. (A) Axial T2-weighted, (B) dynamic contrast enhanced and (C) post gadolinium sagittal T1-weighted images showing a submucosal broad-based mass (arrows) arising from the left posterior aspect of the esophageal wall and bulging into the esophageal lumen.

Figure 5 – Incidental finding of an esophageal duplication cyst in a 41 year-old male. Axial (A) and coronal (B) T2-weighted images show a small mass with cystic MR features (arrow) on the right lateral of the distal esophagus.

Figure 6 –Incidental finding of a gastric lipoma in a 73-year-old male with liver cirrhosis. Axial T2-weighted images without (A) and with (B) fat suppression and T1-weighted in- (C) and out- (D) of-phase acquisitions showing a small submucosal mass (arrows) in the gastric antrum that contains adipose tissue.

Figure 7 – Gastrointestinal stromal tumor (GIST) of the greater curvature in a 39-year-old female. Axial T2-weighted (A), dynamic contrast enhanced (B), diffusion-weighted (C), ADC map (D) and coronal post gadolinium T1-weighted imagesshowing a lesion (arrows) with equal to high-signal intensity (with respect to the normal gastric wall) on T2-weighted imaging and strong, persistent enhancement after gadolinium.

Figure 8 – Lesion involving the distal part of the esophagus in a 66-year-old male. The arrows indicate a slight thickening of the esophageal wall on axial T2-weighted (A), dynamic contrast enhanced (B), diffusion weighted imaging (C), ADC map (D) and coronal T2-weighted (E) images
The ADC value of the lesion was 1.58×10^{-3} mm^2/s.
Final pathology demonstrated esophageal adenocarcinoma (pT3N1).

Figure 9 – Lesion of the middle part of the esophagus in a 59-year-old male before (A-E) and after (F-J) neoadjuvant chemoradiotherapy. The arrows indicate thickening of the esophageal wall on axial T2-WI weighted image (A and F), dynamic contrast enhanced study (B and G), diffusion

weighted imaging (C and H) and corresponding apparent diffusion coefficient (ADC) map (D and I). The ADC of the lesion was 1.42 (before therapy) and 1.92 (after therapy) x 10^{-3} mm^2/s. is Axial T2-weighted images (E and J) showing perilesional lymphadenopathy (arrowheads) that decreased in size after therapy. Final pathology demonstrated esophageal squamocellular carcinoma (ypT2pN3; Tumor regression grade according to Mandard: 3).

Figure 10 – 71-year-old man with local recurrence at the anastomosis site 14 months after esophagectomy for squamocellular carcinoma of the esophagus (pT3pN0). The arrows indicate a gross anastomotic thickening on axial T2-weighted (A), dynamic contrast enhanced (B), diffusion-weighted (C) and ADC map (D) and sagittal (E) post gadolinium T1-weighted image. The ADC value of the lesion was 0.82 x 10^{-3} mm^2/s.

Figure 11 – Lesion involving the gastric cardia (Siewert type III) in a 52 year-old male. The arrows indicate gross thickening of the gastric wall on axial T2-weighted (A), dynamic contrast enhanced (B), diffusion-weighted imaging (C) and ADC map (D) images. The ADC value of the lesion was 0.58 x 10^{-3} mm^2/s. Final pathology demonstrated gastric adenocarcinoma (pT3N3a).

Figure 12 – Lesion involving the gastric fundus in a 76-year-old woman. The arrows indicate gross thickening of the gastric wall on axial T2-

weighted (A), dynamic contrast enhanced (B), diffusion weighted imaging (C), ADC map (D) and coronal T2-weighted (E) images The ADC value of the lesion was 0.76 x 10^{-3} mm^2/s.
Final pathology demonstrated gatstric adenocarcinoma (pT3N3a).

Figure 13 – In vivo axial T2-weighted image (A) of a gross lesion (adenocarcinoma) involving the gastric body (arrow) with lymphadenopathy (arrow head). T2-weighted imaging of the ex-vivo specimen (B) and corresponding histology.

Figure 14 - Adenocarcinoma of the gastric cardia (Siewert II) in a 48 year-old male before (A-D) and after (E-H) neoadjuvant chemotherapy. The arrows indicate the lesion on axial T2-WI weighted image (A and E), dynamic contrast enhanced study (B and F), diffusion weighted imaging (C and G) and corresponding apparent diffusion coefficient (ADC) map (D and H). The ADC of the lesion was 1.15 (before therapy) and 2.75 (after therapy) x 10^{-3} mm^2/s.
Final pathology demonstrated complete response (ypT0pN0; Tumor regression grade according to Mandard: 1).