VIRTUAL GASTROINTESTINAL TRACT
VIGOR++

Deliverable 7.1

Clinical Application Scenario

AMC

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1. Summary

Magnetic resonance imaging is increasingly used for abdominal evaluation and is more and more considered as the optimal imaging technique for detection of mural inflammation in patients with Crohn's disease. Grading the disease activity is important in daily clinical practice to monitor the medical treatment and is assessed by evaluating different Magnetic Resonance Imaging features. Unfortunately, only moderate interobserver agreement is reported for most of the subjective features and should be improved. A computer-assisted model for automatic detection of abnormalities, ability to grade disease severity, and thereby influence clinical disease management based on Magnetic Resonance Imaging is missing.

2. Introduction

Abdominal Magnetic Resonance Imaging (MRI) is widely used for diagnosing and grading luminal Crohn's disease (CD). It typically involves a luminal (oral) and an intravenous contrast medium in order to combine transmural and extra-intestinal evaluation of disease activity. Grading disease activity is important in daily clinical practice to monitor the often costly and burdensome medical treatment and define treatment strategies. Additionally, pharmaceutical trials increasingly employ MRI as outcome measure.

Conventionally, disease activity is assessed by evaluating the presence of mural changes (e.g. wall enhancement, bowel wall thickening, wall edema and stratification), stenoses, length of the involved segments, skip lesions and complications (e.g. fistulas). In fact, almost all articles on MRI in luminal CD use these MRI features for assessment of disease activity and these features are considered most important by international experts.

However, grading the disease activity based on these MRI features has intrinsic limitations related to restrictions of the MRI technique. Also, it is a subjective evaluation while varying weight is attributed to these features. For instance, Jensen et al. found only moderate interobserver agreement (kappa = 0.48) in detection of CD with MR enterography. Another recent study by Ziech et al. reported a weak to moderate interobserver agreement for most of the subjective MRI features. This is in accordance with other studies comparing interobserver variability of subjective MRI features. A questionnaire among international research groups showed that different weight is given to certain features and different grading systems are used, hampering comparison of study results. For example, some reviews presented absolute contrast enhancement as a marker of disease activity, while others dispute this. Based on the present methods of grading, MRI has been shown to be accurate for severe disease (in 91% of cases accurate grading), but mediocre for mild disease or remission (accurate grading in only 62% of cases).

Clearly, a system is preferred that renders a fine grading of the disease severity for accurate treatment monitoring. Further, for surgical treatment the location of the disease and the length of the involved segments are important as well. At present the

radiologist's reading of the length of involved segments is relatively cumbersome and no data are available on the accuracy and the precision.

For an optimal evaluation of response monitoring, MRI should be a robust, objective and reproducible technique. Applying a (semi-)automated method might improve the interobserver variation and allow a finer diagnosis scale as compared to the gross scale (remission – mild – severe) used by the radiologist. Therefore, development of computer-assisted diagnosis tools for quantitative image-based analysis of CD is pivotal.

3. Future scenario case

Dr. Gerard is an experienced radiologist and is working at both the local hospital and the body-scanning center. In the hospital his work primarily concerns the imaging diagnostics. At the scanning center, Dr. Gerard has the final responsibility for the follow-up and monitoring of the patients.

Although he always wanted to work at both places, this became practically feasible by the introduction of new techniques in the scanning center. If he is on duty, as soon as new imaging data sets become available in the scanning center he is notified to review them. He can use any computer system or mobile handheld device he prefers, at home, at work or while travelling and directly report the images just made. There is a meeting with the other involved physicians to discuss the patients from the scanning centre at regular intervals.

Today, several patients are coming to the scanning center to update their virtual gastrointestinal (GI) tract model. Dr. Gerard is on duty; an automated process manages the body-scanning center and makes sure everything runs smoothly for the patients there.

This is a big improvement compared to the old days, when Dr. Gerard had to assess each scan again and again. First, he downloaded and looked to the older scans of a single patient. Afterwards, he looked at the new scan, the T1-weighted sequences on the left and the T2-weighted sequences on the right screen, so he could compare these images with each other. Then he reported the T1- and T2-weighted sequences of the scan and the differences with the older scans. High levels of experience and concentration was critical to report, compare and describe everything as good as possible.

Fortunately, the new tools can detect the GI tract model changes now. The T1- and T2-weighted sequences are automatically superimposed and analyzed against the images from several years ago. Minimal differences are critical to report in chronic diseases, especially those without a known cure. Currently, they are identified, highlighted on the screen, ranked based on a severity index and sent to the radiologist. Dr. Gerard has more detailed and objective information now at a single glance than even when combining several screenshots from 15 years ago.

Development of such a system was a complex task, particularly due to the signal fluctuation inherent to MRI. Moreover, the limited thickness of the bowel wall and the

presence of peristalsis further complicated the development of new techniques. A combination of (semi-)automated segmentation and different registration techniques to identify, respectively align regions of interest in MRI images was finally used to develop the system. Nowadays it facilitates the measurement of descriptive properties of CD activity in the images. Pattern recognition techniques detect and rate abnormalities. The latter supported the establishment of the combined, objective and quantitative disease severity index.

Ten years ago, important steps were made using semi-automated identification of the bowel wall surface. A radiologist could manually select a region in an intestinal segment where CD activity is expected. Subsequently, the model identified the bowel wall, from which the wall thickness and enhancement was deduced. Additionally, the model might gave the length of the affected part of the segment. The model assisted the radiologist in this way by objectively quantifying features of the affected bowel segment, which was already very useful in the follow-up of patients.

This afternoon, Dr. Gerard reports a flare up of patient Jane's disease and sends the update of the GI tract model, with the associated images and diagnostic report, to her gastroenterologist Dr. Antony. The changes in her GI tact model suggest that the medication dosage can be reduced. Dr. Antony approves the report and agrees to reduce Jane's medication using Siri, a voice-activated personal assistant. The new tools enable Dr. Antony to devote more time on patient consultations than before, including Jane's father Roger.

Roger's misfortune is that he was diagnosed with Crohn's disease more than 20 years ago. Part of his bowel was removed after the endoscopy showed an inflammation of the bowel. In those days, the surgeon depended on the gastroenterologist's opinion whether or not he had to operate. He could not properly assess the results of investigations during the operation. The operation lasted half an hour longer than planned, because there was a possible second stenosis seen behind the first one. As a result roger has had more than 30 centimeters of his bowel removed, while the inflammation was only 5 cm long and could have been treated with medication.
Using the GI tract model this would not have been necessary. With the advanced MRI and the ability to monitor the evolution of personalized GI tract model, the surgeon could have seen the exact location(s) of the inflammation. If Roger was to take that operation now, he would have left the operating table within 45 minutes and have gone home the next day. This is enabled by the widespread usage of laparoscopic operations.

Despite his problems, he is optimistic about the impact of the new tools particularly for the younger generations. .This kind of situation will probably not happen to his daughter Jane thanks to the annual non-invasive examination conducted by Dr. Gerard and Dr. Antony in the body scanning center.

4. Conclusion

(Semi-)automated assessment of Crohn's disease is not fiction anymore as already limited tools are available. However, substantial steps have to be made to come to robust (semi-)automated assessment tools. It would be a ground-breaking development

if the radiologist could be assisted by automatic detection and quantification of abnormalities at MRI of the gastrointestinal tract and have an objective assessment of disease severity.
To that end ICT tools should be created that extract regions of interest (semi-)automatically from MRI data, analyze the small bowel by use of mural features, use a classifier to predict the presence of active Crohn‘s disease and the ability to grade disease severity in the near future.