Image Evaluation in Magnetic Resonance Cholangiopancreatography

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Abstract: The objective of this study is to evaluate the image quality with two different contrast agents in MRCP compared to medical evaluation and by using the software Image J®. Natural juices and pulps of different types (açai liquid and powder; and blend) were selected. The selection of patients (31 women and 33 men) was performed at Clinical Hospital, which provides general care in Curitiba city (Brazil). The application of the MRCP protocol followed a sequence tested in healthy volunteers and for the samples described. For image analysis, 2 radiologists participated and were identified as evaluator 1 (E1) and 2 (E2), in order to identify the effect of the contrasts on the images. For the 6 samples tested, only 2 samples remained dark on T2 weighting, which prevents their use as contrast agent. The evaluation of the images was performed separately for each evaluator on different days and places, to identify an appropriate action for the contrasts (A and B). The use of the software (Image J®) allowed a less subjective analysis of the image quality when compared to the evaluation of radiologists and, for the examples presented, a quantitative assessment since the chosen images were submitted to the software analysis.

1 INTRODUCTION

The acquisition of images by magnetic resonance (MRI) has the advantage to turn easier the views of soft tissues as well as organs of difficult access compared to other imaging methods (e. g., X-rays and computerized tomography). However, to obtain quality images, it is important that they can show areas of intense (white), weak (dark) and intermediate (gray levels) signals (Westbrook, Roth and Talbot, 2011; Jornada, Murata and Medeiros, 2016).

Among the types of MR image acquisitions, this study is concerned to Magnetic Resonance Cholangiopancreatography (MRCP). This technique makes use of a negative contrast to identify and to show parts of the gastrointestinal system, in particular the images of the pancreas and gall- bladder which are superimposed (Xiao and Zhang, 2010). The contrast to be used can be manufactured or natural. The use of a natural contrast, as the juice of some fruit, is more indicated since it does not cause adverse reactions and present an image similar to a manufactured one (Fraga et al., 2004; Pinho et al., 2019). A juice as contrast agent must be paramagnetic; act as biphasic contrast (showing up positive for T1 sequences and, negative for T2); be uniformly distributed in the digestive cavity and small intestine; non-toxic; and be affordable (Duarte, Furtado and Marroni, 2012). The contrast agents should have some metals that help in identifying the image, such as iron (Fe) and manganese (Mn). These can be found in juices (pineapple, açai and blueberry), teas and specific preparations (Ghanaati et al., 2011; Griffin, Edwards and Grant, 2012; Renzulli et al., 2019).

Oral contrast agents in MRCP examinations must present a low signal in weighted T2, with negative

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contrast effect in the region impregnated with the contrast (Mantau et al., 2014). In the case of the MRCP, it is important to eliminate the stomach (Figure 1, arrow 1) duodenum signals (Figure 1, arrows 2) and to facilitate the visualization of gall-bladder (Figure 1, arrow 3), common bile (Figure 1, arrow 4a) and pancreatic ducts region (Figure 1, arrow 4b).

The objective of this study is to evaluate the image quality with two different contrast agents in MRCP compared to medical evaluation and its confirmation by the software Image J® (Souza et al., 2014). This software was used to verify if both contrasts could present overall MRCP equivalent image quality.

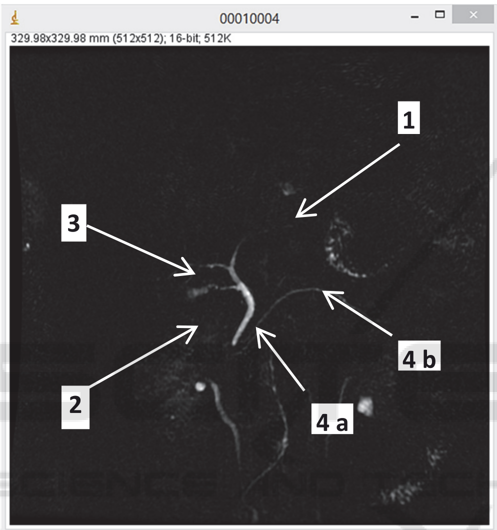

Figure 1: MRCP image after negative oral contrast administration. Arrows indicate: (1) the stomach region and (2) the duodenum, both erased by contrast action, (3) the gallbladder and (4a) the common bile duct and (4b) pancreatic duct region.

2 MATERIALS AND METHODS

The research project was approved by UTFPR Ethics Committee (number 02.520.512.0.0000.5547.

The selection of patients (31 women and 33 men) was performed at the Clinical Hospital of the Federal University of Paraná (UFPR), which provides general care in Curitiba city (Brazil). The patients were selected from the outpatient clinics of liver and fat correlated diseases of the Hospital. Experiments were produced to select the juice and MRCP exams were performed in a Diagnostic Clinic of Curitiba city.

2.1 MRCP Protocol

2.1.1 Experiments with Phantom

Initially, natural juices and pulps of different types (açai liquid and powder; and blend) were selected. Afterwards, they were placed in a water container, as shown in Figure 2, and tested on a 1.5T MRI system from General Electric Company (GE), model HDXT with 12 channels, GE Healthcare Advantage workstation running Centricity DICOM Viewer version 3.0 software in the Clinic above. The protocol determination of the samples was the same as that used by the clinic for the examination of MRCP. Initially: localizer (LOC) in 3 orthogonal planes (PL) following Single-Shot (SS), Fast Spin Echo (FSE) in apnea (LOC 3 PL SSFSE Apnea); radial cholangio and axial lava T1 without fat (Pinho et al., 2014; Pinho et al., 2018).

The parameters of the T1 weighting protocol were: LAVA TR/TE 4.2/2.0 ms; FOV: 36x32 mm; 320x160; slice thickness: 4.0 mm and 0.70 NEX; inversion time (TI): 7.0 ms. For T2: acquisition in Fast Imaging Employing Steady-State (Fiesta)/TR/TE 4.4/2.0 ms; FOV: 36x36 mm; 224x320; slice thickness: 3.0 mm; 1.0 NEX: inversion time: 200 ms (Westbrook, 2010; Pinho et al., 2018).

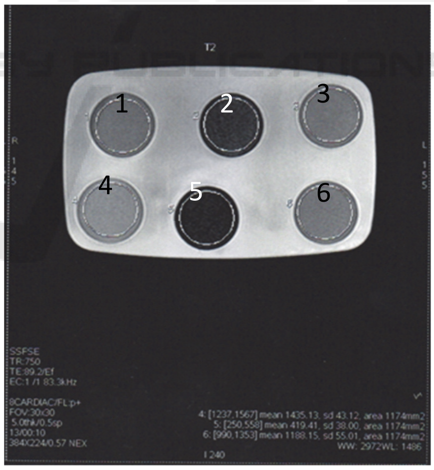

Figure 2: T2 sequence of image of açai samples and commercial contrast. Identification was performed from left to right, with numbers 1, 2 and 3 above, and 4, 5 and 6 below.

The phantom tests were carried out with six samples of açai juice of different brands and with different water concentrations. Figure 2 illustrates these samples, which can be identified as follows, respectively:

1- Açai 100 g /100 mL of water;
2- Açai powder with 13 g /100 mL of water;
3- Commercial contrast;
4- Açai frozen with 100 g /100 mL of water;
5- Açai more concentrated, 100 g/80 mL of water;
6- Açai powder with 6g /100 mL of water.

2.1.2 Experiments with Patients

The MRCP examination protocol was the same as for the samples of juices described above, besides the acquisition of multiple thin slices in the coronal plane for this work: Half Acquisition Single Shot Turbo Echo (HASTE), Turbo Spin Echo (TSE), following thick radial cuts in FSE/TSE also with strong weighting in T2. Here the cutting plan is directed to the distal common bile duct. The acquisitions were made in Axial 2D FIESTA (with fat saturation) Array Spatial Sensitivity Encoding Technique (ASSET) and the radial cholangio sequence for two days of tests, in order to compare the effectiveness of contrasts (Sanchez et al., 2009; Pinho et al., 2018).

Each patient was identified by the respective gender after a cardinal number (female, male), e.g.: F1, M2 to facilitate image acquisition and storage.

The application of the MRCP protocol followed a sequence tested in healthy volunteers. In addition, doctors were available to perform MRCP exams in that clinic. Since the patients would need the examination report, on the first day a commercial contrast (labeled A) was administered with a total abdominal sequence and administration. On the second day the natural contrast of açai juice (labeled as B) was administered, and after the sequence of MRCP was started. The dose of each contrast was 200 mL divided into 2 portions of 100 mL, one dose was given after the anamnesis and another 10 minutes later (Pinho et al., 2018).

2.2 Image Evaluation

For image analysis, 2 radiologists participated and were identified (this study) as evaluator 1 (E1) and 2 (E2), both with experience in the field of diagnostic imaging, in order to identify the effect of the contrasts on the images.

After the exams were completed, the images were saved in the PACS (Picture Archiving and Communication System) (Marques et al., 2005) system and available on file so that each evaluator could access and analyze the effects of the contrasts (commercial and natural), according to the scale from 1 to 4. By observing the regions of interest for examining MRCP, i.e,. the oral contrast should erase the sign of the stomach and duodenum. Score 1 means that there is a hyperintensity signal of stomach and duodenum and it is not possible to evaluate these structures. Score 2: assessment occurs when there is a partial view of the structures. In score 3, hyperintensity signal does not hinder the analysis of the structures, and score 4 means that there is no signal hyperintensity for stomach and duodenum, which makes clearer the MRCP image (Duarte, Furtado and Marroni, 2012; Pinho et al., 2019).

Image J® software (obtained free from http://imagej.nih.gov) was employed to analyze and compare the image quality of the patients by separating a common bile duct region, with the same dimension (selection rectangle with size approximately 97.85 mm x 2.58 mm (length and height)), in Figures 4, 5, 6 e 7. The chosen sections of the Figures were selected by the radiologists and used later for the Image J® estimation of gray levels since those regions are used for medical evaluation in order to detect physiological alteration or correlated diseases. For the construction of the figures with Image J®, the length corresponds to the anatomical region of interest and the value to gray levels (intensity pixels). For that, it was chosen among the assessed medical images, which ones showed a coincidence between the two MRCP sequences for the two contrasts, and about same scores provided by the evaluators (Brianezi, Camargo and Miot, 2009; Pinho et al., 2019).

3 RESULTS

3.1 Experiments with Phantom

For the 6 samples tested, only 2 (sample 2 of açai powder and 5 of açai more concentrated) remained dark on T2 weighting, which prevents their use as contrast agent. It is observed that in the T2 sequence presented, the dark images of the juices and mixtures provided the details required in the MRCP examination, since for the bile and pancreatic images acquisition, the administered contrast must eliminate the residual signal.

The images of açai samples taken from Figure 2 were handled and their Regions of Interest (ROI) values were measured. The best samples were 1, 3, 4 and 6 for T1 and T2 weighting, as seen in Figure 3. ROI values of T1 weighting should be as great as possible, and the values obtained were ≥ 1038 (samples 1, 3, 4 and 6). The value of 527.6 of substance 3 is not compatible in T2 since it was low compared to the others. Also in Figure 2 for T2, ROI values of the samples must be higher because the expected behavior is present in the image (darker), and the amounts obtained were 1037.7 (sample 1); 527.6 (2); 1111.8 (3); 1435.1 (4); 419.4 (5) and 1188. 2 (sample 6).

The best samples for T2 were 1, 3, 4 and 6. It was decided to use the sample 1 for ease of acquisition and availability.

3.2 Patients and Image Analysis

The application of the MRCP protocol for 64 patients produced 12 acquisitions were obtained with contrast A as well as 12 with contrast B (1x12x12=144 MRCP images). In order to present the analysis method using Image J® to compare the images and, considering the individual characteristics of patients, quantity and complexity of information provided by the number of images for each patient on 2 days of exams, it was decided to present the results for 2 patients (M43 and M5). One case is considered more complex and the other is simple, but both need the action of the contrasts to show the organs and/or to observe existent diseases when pertinent and thus proving that Image J® can be used for all practical cases.

Image Evaluation

The evaluation of the images was performed separately for each evaluator on different days and places; they have chosen within the MRCP sequence two images to identify an appropriate action for the contrasts (A and B), one for each type of contrast.

Figure 3 shows an image acquired with contrast A and, Figure 4 an image acquired with contrast B for the radial cholangio sequence of patient M43. Both images had scores 3 from evaluators E1 and E2 on 2 days. The medical report for patient M43 described a small ascites in the hepatic region (more visible in Figure 3, arrow 1), chronic liver disease, distended gallbladder and with thickened walls, with better anatomic view in Figure 4 (arrow 2).

It is noted that on the two images (Figure 3 and 4) there was reduced signals from the stomach and duodenum, showing the complete bile duct. The Figures above have shown adequate white levels (gallbladder region, arrows 2 and, common bile duct, arrows 3) and dark levels for stomach and duodenum (Figure 1, arrows 1 and 2), as must be present for a quality medical report of MRCP.

Figure 5 shows an image acquired with contrast A and, Figure 6 an image acquired with contrast B for the radial cholangio sequence of patient M5. Both images had scores 3 from evaluators E1 and E2 on first day for contrast A. On second day, considering contrast B, E1 assigned score 3 and, E2 score 4. The medical report described that fat liver and the other organs (gallbladder, pancreas and ducts) were with normal anatomic aspect.

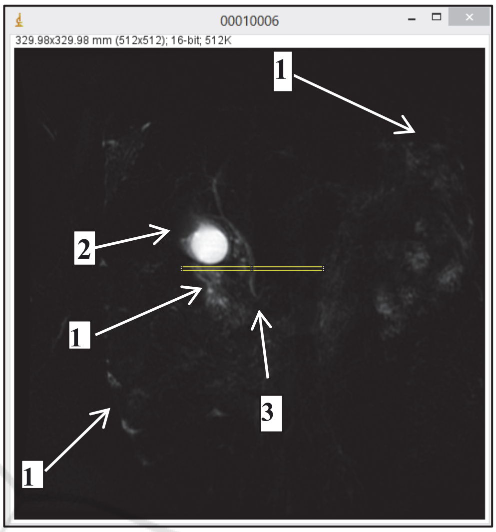

Figure 3: Image from patient M43 which had a score 3 with contrast A. Arrows indicate: (1) ascites region; (2) gallbladder; (3) common bile duct. The rectangle indicates the area of the common bile duct, chosen for the software Image J®.

The Figures 5 and 6 have shown both contrast with pretty similar images for MRCP, exception for organs without interest as kidney and large intestine. The images (Figures 5 and 6) show adequate white levels (gallbladder region, arrows 2 and, common bile duct, arrows 3). Particularly for Figure 5 (arrow 1), the stomach region presented some points with white levels where it should be dark.

The software Image J® was applied to Figures 3, 4, 5 and 6 generating a quantitative analysis of a selected section of the common bile duct, close to the duodenum. The arrows indicate the selected areas of approximately 97.85 mm x 2.58 mm. The areas were taken to build the curves of Figures 7 and 8 which show the gray levels (pixels) as a function of distance (width duct) for contrasts A and B. For both Figures (7 and 8), arrows (1) indicate the duodenum and gallbladder region, arrows (2) the common bile duct, arrows (3) the pancreatic duct and, arrows (4) the pancreas region.

Figure 7 shows curves as obtained with data from Figures 3 and 4 and the software Image J®. For regions (1) e (2) a peak value with gray levels (600.8)

Figure 4: Image from patient M43 which had a score 3 with contrast B. Arrows indicate: (1) ascites region; (2) gallbladder; (3) common bile duct. The rectangle indicates the area of the common bile duct, chosen for the software Image J.

Figure 5: Image from patient M5 which had a score 3 with contrast A. Arrows indicate: (1) duodenum region; (2) gallbladder; (3) common bile duct. The rectangle indicates the area of the common bile duct, chosen for the software Image J®.

was obtained at position 11.6, due to the presence of ascites around the gallbladder (see Figure 3, rectangle) as obtained with contrast A. Considering the same region for contrast B, the values were quite different. For region (3) the peak values were 365.5 (contrast A) and 284.5 (contrast B) close to point 50.3. For points from 0 to 46.4 (regions 1 and 2), a correlation coefficient of 0.13 was calculated for the

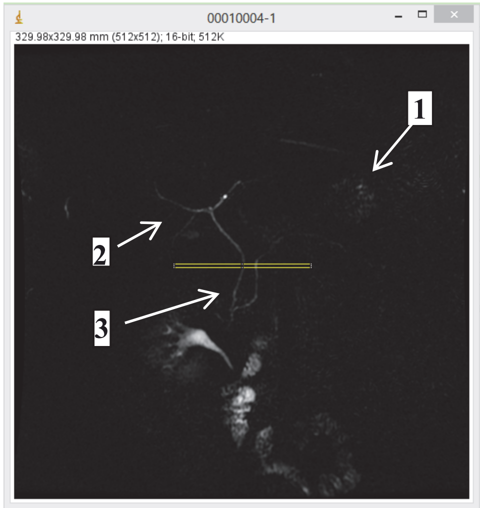

Figure 6: Image from patient M5 which had a score 3 with contrast B (E1) and score 4 (E2). Arrows indicate: (1) duodenum region; (2) gallbladder; (3) common bile duct. The rectangle indicates the area of the common bile duct, chosen for the software Image J®.

gray levels of both contrasts. This is related to ascites which caused some blanching over the image (Figure 4 arrow 1).

The average intensities of the same points for contrast A was 316.6 and 113 for contrast B. Considering region (3) which is important for an MRCP medical report, the correlation between gray levels was 0.95 among points from 46.4 to 54.1. The average values for this region were 216.1 for contrast A and, 166.4 for contrast B.

Figure 8 shows the curves as obtained with data from Figures 5 and 6 and the software Image J®. It shows (Figure 8) great similarity between curves for contrasts A and B. The correlation coefficient among all points (0 to 100) for gray levels was 0.92. The average gray levels for points (0 to 46.4) were 32.2 and 35.7 for contrasts A and B, respectively. Taking regions (2) and (3) from points 47.4 up to 60.6mm, the average intensity for contrast A was 80.7 and 74.8 for contrast B.

4 DISCUSSION

The ROI values obtained for the açai samples showed that for T2 with the higher values, they can be used as contrast agent in MRCP, according to other authors (Fraga et al., 2004; Espinosa et al., 2006 and Pinho et al., 2019). Note that the açai value (sample 1) was close to the commercial contrast (sample 3).

Two radiologists evaluated the images obtained in MRCP exams giving notes from 1 to 4. Two MRCP examples were selected (patient M43 e M5) to produce a quantitative analysis employing Image J®. For the example (M43) presented, the images received the same notes (3) from both evaluators, using the commercial contrast (A) and açai juice (B). For case M5, both images had scores 3 from evaluators E1 and E2 on 1st day for contrast A. On 2nd day, considering contrast B, E1 assigned score 3 and, E2 score 4.

The chosen images, by both evaluators for M43 patient, are equal within the MRCP sequences. Considering Figure 3, the gallbladder did not present all the contours, differing from Figure 4 (where it showed). This organ presents great motility with time what can explain the differences between Figures 3 and 4 (arrows 2), besides the variability of food ingestion, which alters gallbladder physiology.

For patient M43 (Figure 7), Image J® presented gray levels with peak value of 600.8 and average value of 316.6 for regions 1 and 2 on first day. These values are bigger than those presented on second day. The higher values are explained by means of Figure 3 since the ascites was more visible. The correlation coefficient between contrasts curves was pretty low for regions 1 and 2 due to the high variability of ascites viewing. Taking only region 3, the correlation is very high (0.95), what shows that both contrasts are acting very well within the common bile duct.

Taking Figure 8 (Image J®) for M5 patient, there were clean regions showing the common bile duct, with gray average intensity of 32.2 (contrast A) for region 1 (duodenum and gallbladder) and 35.7 (contrast B). For regions 2 and 3, which are important to find out anatomical alteration or diseases, average intensity was 80.7 (contrast A) and 74.8 (contrast B) meaning that both contrasts had similar values and clear views of the common bile and pancreatic ducts regions, as expected for an oral negative contrast. Also, evaluators noticed no difference between contrasts.

The limitations of the work are related to the fact that there is no known association between the artifacts present in the image and the evaluators' grades. Artifacts can be from the equipment (lack of quality control) and/or from the patient. The artifacts from the patient may be due to illness, lack of adequate preparation for the exam, physiological changes and others. These modify the image quality, as well as the note of the evaluator.

Image J® software showed for the cases described, the one with presence of diseases there was increase of average gray level (patient M43) for ascites (about 113), while for patient M5 (normal MRCP) the average was low (about 36).

5 CONCLUSIONS

The present study aimed to evaluate the image quality with two different contrast agents (commercial and

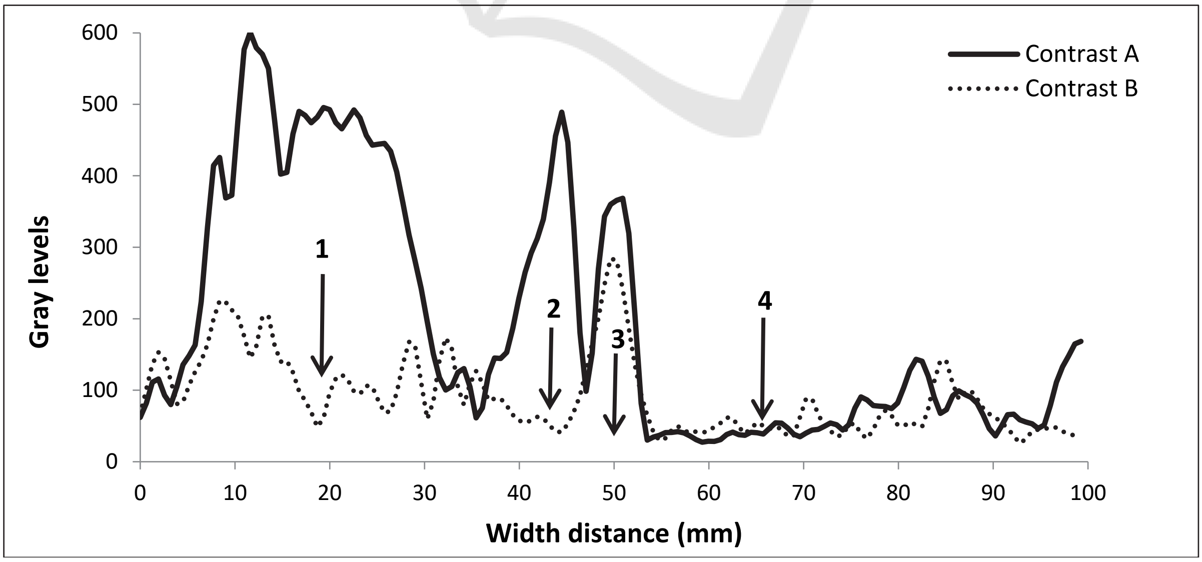

Figure 7: Plots of the selected regions of radial cholangio images from the common bile duct of patient M43 as obtained with the software Image J® The curves represent the gray levels against distance for contrasts A and B. Arrows indicate: (1) duodenum region and gallbladder; (2) near common bile duct; (3) common bile duct and, (4) pancreas body.

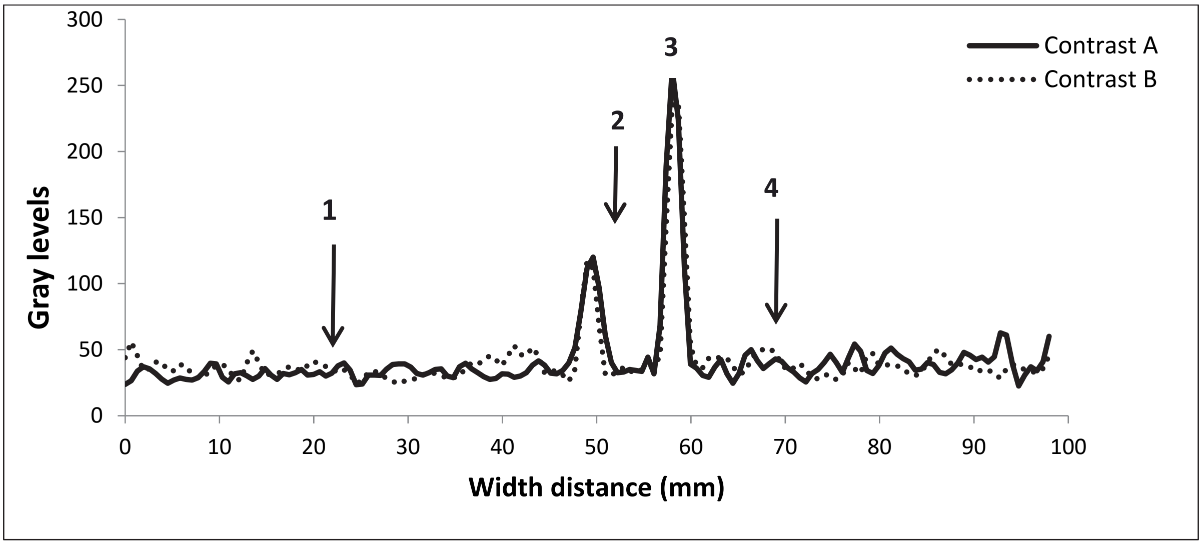

Figure 8: Plots of the selected regions of radial cholangio images from the common bile duct of patient M5 as obtained with the software Image J®. The curves represent the gray levels against distance for contrasts A and B. Arrows indicate: (1) duodenum region and gallbladder; (2) common bile duct; (3) pancreatic duct and, (4) pancreas body.

natural) in MRCP compared to medical evaluation and confirmation by the software Image J®.

The natural contrast (açai) was able to erase the signal from the stomach and duodenum (as shown), as well as enhanced signal to the common bile duct, as it should be in the clinic for a quality image in MRCP.

The use of the software (Image J®) allowed a less subjective analysis of the image quality when compared to the evaluation of radiologists and, for the examples presented (patients M43 and M5), a quantitative assessment since the chosen images were submitted to the software analysis. Thus, the gray levels intensities obtained with the software Image J® corroborates the view of the evaluators E1 and E2 with the images. Anyhow, the results open an excellent opportunity for further studies, to establish an automated protocol that uses available software since it was useful to confirm the existence or not of anatomical alteration and/or diseases.

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