ORIGINAL ARTICLE

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The Effective Method of Monitoring Visceral Organ Fatty Infiltration Changes After Bariatric Surgery: Ideal IQ Sequence

Bariatrik Cerrahi Sonrası Viseral Organ Yağ İnfiltrasyon Değişikliklerini İzlemenin Etkili Yöntemi: İdeal IQ Sekansı

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ABSTRACT

Aim: The aim of this study is to demonstrate the efficiency of non-invasive imaging method-MR proton density fat fraction (PDFF); ideal IQ sequence- on detecting the effects of bariatric surgery on liver and pancreatic fatty infiltration.

Materials and Methods: Thirty-nine patients (25 females, 14 males) who underwent bariatric surgery between May 2016 and April 2017 were analyzed retrospectively in this study. Body mass index (BMI) and body weight (BW) values of all patients were noted one week before and one month after bariatric surgery, and meanwhile an unenhanced upper abdominal MR imaging was performed. Liver fat fraction (LFF), pancreas fat fraction (PFF), liver volume (LV) and craniocaudal length of liver (LL) were measured with MR-PDFF and T2 weighted images. Changes in all parameters after the surgery were recorded and the correlation of these changes with the change in LFF was analyzed.

Results: At the end of first month of bariatric surgery, a significant decrease on mean values of LFF and PFF has been observed along with a decrease of LV, LL, BW and BMI ($p<0.0001$). A moderate positive linear correlation was observed between LFF and PFF, LV, LL ($r=0.69$, 0.61, 0.49; respectively) while a weak positive linear correlation was noticed between LFF and BMI, BW ($r=0.34$, 0.21; respectively).

Conclusion: Ideal IQ sequence enables quantitative analysis of fatty infiltration of the liver and pancreas and thus may be used as a non-invasive tool to monitor the positive effects of the bariatric surgery on fatty infiltration of these visceral organs in the postoperative period.

Keywords: Bariatric surgery, magnetic resonance imaging, non-alcoholic fatty liver, pancreatic disease, proton-density fat fraction

ÖZ

Amaç: Bariatrik cerrahinin karaciğer ve pankreas yağ infiltrasyonu üzerindeki etkilerinin saptanmasında non-invaziv görüntüleme yönteminin-MR proton dansite yağ fraksiyonu (PDFF); ideal IQ sekansı-etkinliğini göstermeyi amaçladık.

Gereç ve Yöntem: Bu çalışmada Mayıs 2016 ile Nisan 2017 tarihleri arasında obezite cerrahisi geçiren 39 hasta (25 kadın, 14 erkek) retrospektif olarak incelendi. Tüm hastaların vücut kitle indeksi (VKİ) ve vücut ağırlığı (VA) değerleri bariatrik cerrahiden bir hafta önce ve bir ay sonra kaydedildi ve bu esnada kontrastsız üst abdomen MR görüntülemesi yapıldı. MR-PDFF ve T2 ağırlıklı görüntülerle karaciğer yağ fraksiyonu (KYF), pankreas yağ fraksiyonu (PYF), karaciğer hacmi (KV) ve karaciğer kraniyokaudal uzunluğu (KKU) ölçüldü. Ameliyat sonrası tüm parametrelerdeki değişiklikler kaydedildi ve bu değişikliklerin KYF'deki değişiklik ile korelasyonu analiz edildi.

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Bulgular: Bariatrik cerrahinin 1. ayının sonunda KYF ve PYF ortalama değerlerinde anlamlı azalma ile birlikte KV, KKU, VA ve VKİ'de azalma gözlendi (p<0,0001). KYF ile PYF, KV, KKU arasında orta derecede pozitif bir doğrusal korelasyon gözlenirken (sırasıyla r=0,69, 0,61, 0,49), KYF ile VKİ, VA arasında (sırasıyla r=0,34, 0,21) zayıf bir pozitif doğrusal korelasyon fark edildi.

Sonuç: İdeal IQ sekansı, karaciğer ve pankreasın yağ infiltrasyonunun kantitatif analizini sağlar ve bu nedenle postoperatif dönemde bariatrik cerrahinin bu viseral organların yağ infiltrasyonu üzerindeki olumlu etkilerini izlemek için non-invaziv bir araç olarak kullanılabilir.

Anahtar Kelimeler: Bariatrik cerrahi, manyetik rezonans görüntüleme, alkolsüz yağlı karaciğer, pankreas hastalığı, proton dansite yağ fraksiyonu

INTRODUCTION

Obesity may result in various health problems such as coronary artery disease, cerebrovascular disease, and metabolic syndrome, in addition to fatty liver and pancreas diseases[1]. Non-alcoholic fatty liver disease (NAFLD) is present in 70-95% of obese patients. This condition may range from simple steatosis, or from a non-alcoholic steatohepatitis (NASH), to cirrhosis and even to hepatocellular carcinoma[2,3].

Pancreas is the other visceral organ in which ectopic fat accumulation secondary to obesity is frequently observed. Non-alcoholic fatty pancreas disease (NAFPD) is pancreatic fatty infiltration due to obesity. Just as NAFLD progresses to non-alcoholic steatohepatitis (NASH) over time, it is possible for NAFPD to progress to non-alcoholic steoatopancreatitis due to the failure of the metabolic condition over time, and as a result, pancreatitis and pancreatic cancer may develop[4-8].

Quantitative evaluation of fatty infiltration in the liver and pancreatic parenchyma is of great importance for correct diagnosis and treatment. The gold standard method used for this purpose is liver biopsy[9,10]. However, this procedure is invasive and has the disadvantage of complications such as hemorrhage and infection, and evaluation of only a limited section of the liver, which may necessitate new diagnostic methods. Recent studies have shown that various magnetic resonance (MR) imaging (MRI) techniques provide accurate information about the amount of fat in the liver parenchyma similar to liver biopsy. These techniques, besides being reported to be non-invasive, have also the advantage to allow the monitoring of fatty liver disease[11-15]. There is no clear consensus yet on diagnostic methods that can determine the amount of pancreatic fat at an optimum level. However, reviewing the literature, MRI with its non-invasive nature and high sensitivity, is reported to be the most preferred diagnostic imaging method used for this purpose, today. Furthermore, a novel MR-proton density fat fraction (PDFF) method also allows high accuracy quantification of pancreatic fat infiltration[16-18].

Fatty liver disease is frequently observed in patients who are candidates for bariatric surgery, and 25% of these patients have NASH and 1-3% have cirrhosis[19]. NAFLD and secondary parenchymal damage due to fatty infiltration has been shown to be resolved and even completely returned to normal after bariatric surgery in up to 80-92% of the patients[20,21].

Although there are accumulating data on the effects of bariatric surgery on NAFLD in the literature, there is still a necessity for further studies regarding the effects of bariatric surgery on pancreatic fatty infiltration. In this context, the aim of this study was to demonstrate the effects of bariatric surgery on the liver and pancreatic parenchyma from the early postoperative period with a non-invasive imaging method, ideal IQ sequence (MR-PDFF).

MATERIALS AND METHODS

This retrospective study was approved by the Recep Tayyip Erdoğan University Institutional Review Board in our institution (decision number: 2019/113, approval date: 09.09.2019) and written informed consent was obtained from all patients.

Patient Selection

A total of 55 patients scheduled for bariatric surgery due to morbid obesity between May 2016 and April 2017 were included in this study. Sixteen patients were excluded from the study for various reasons. The study was conducted with remaining 39 patients who underwent bariatric surgery (35 laparoscopic sleeve gastrectomy, 4 laparoscopic Roux-Y-gastric bypass). The patient flow diagram is shown at Figure 1. All patients were examined with unenhanced upper abdominal MRI a week before and a month after surgical intervention.

Assessment

The patients were evaluated by the multi-disciplinary bariatric team, including two surgeons, endocrinologist, endoscopist, anesthesiologist, psychiatrist and specialized nurses, prior to surgical treatment. All of the bariatric operations were performed by two general surgeons (M.K.Ç. and S.K.). Patients were not administered a diet programme before the surgery. But, after bariatric surgery, all patients were included in the diet program determined by the bariatric team.

Inclusion and Exclusion Criteria

Inclusion criteria were body mass index (BMI) of 40 kg/m^2 or BMI ≥35 kg/m^2 and having related comorbidities such as diabetes, hypertension, coronary artery disease, and chronic lung diseases. Patients with any contraindications for MR examination (presence of pacemaker or any metallic implant not compatible with MR and claustrophobia) or known diffuse non-NAFLD liver disease (such as chronic hepatitis B or C, Wilson disease and hemochromatosis) were excluded from the study.

Radiological Measurements

All measurements were performed by a single radiologist (Y.M.) with approximately 8 years of experience in abdominal imaging. On the ideal IQ sequences obtained before and after the surgery in the axial plane, the fat fraction values were measured on the fat fraction maps three times and the mean value was recorded using the 3-cm and 1.5-diameter circular region of interest (ROI) from the liver segment 4A and the pancreas body, respectively. Also, liver volume measurements were made by outlining liver boundaries on each slice at ideal IQ sequence and the final volume was calculated automatically. Liver craniocaudal length (LL) was measured in a coronal T2 W images from the hepatic dome to the lower border of the liver passing through the mid-hepatic point. Also, BMI and BW measurements were performed at preoperative and postoperative periods. BMI was calculated as weight/height^2.

Magnetic Resonance Imaging

All MRIs were obtained at 3T scanner (GE MR750, GE Healthcare, Waukesha, WI, USA) utilizing a multi-channel torso phased-array coil placed over the liver with all subjects in the supine position. Ideal-IQ sequence was used to determine MRI-PDFF. The Ideal-IQ sequence parameters were as follows: repetition time (TR), 5.8 or 6.7 ms; field of view (FOV), 34 cm; NEX, 0.5; matrix, 128×128; bandwidth, 90.91 or 83.33 kHz; flip angle, 3 degree; a slice thickness, 8.0 mm; and acquisition time, 23 s. At our hospital, Ideal-IQ sequence is included in routine MRI protocols for upper abdominal examinations because fatty liver can be easily and quantitatively evaluated by using this sequence. Liver craniocaudal (LL) measurements were performed on coronal single-shot fast spin-echo T2 WI (coronal SSFSE T2WI: TR, 1200-2000 ms; TE, 30-50 ms; matrix, 256×256; FOV, 40 cm; slice thickness, 6.0 mm; NEX, 2; bandwidth 83.33). The images were processed automatically by using the software (AW server 2.0 software; GE, USA) provided by the manufacturer to create water, fat, in phase (IP), out-of phase, R2 star (R2*), and fat fraction maps.

Statistical Analysis

Data analyses were conducted using SPSS 22.0 Statistical Software (SPSS Inc., Chicago, IL, USA). Descriptive statistics, including the means and ranges, were calculated for the age, body weight, BMI, liver fat-fraction, pancreas fat-fraction, craniocaudal length of liver and liver volume for patients. Normal distributions were verified using the Kolmogorov-Smirnov test. The Paired Sample t-test was used to analyze these parameters. Correlation between liver fat-fraction and body weight, BMI, craniocaudal length of liver, liver volume and pancreas fat-fraction was analyzed using the Pearson's correlation analysis. A p value less than 0.05 indicated statistical significance.

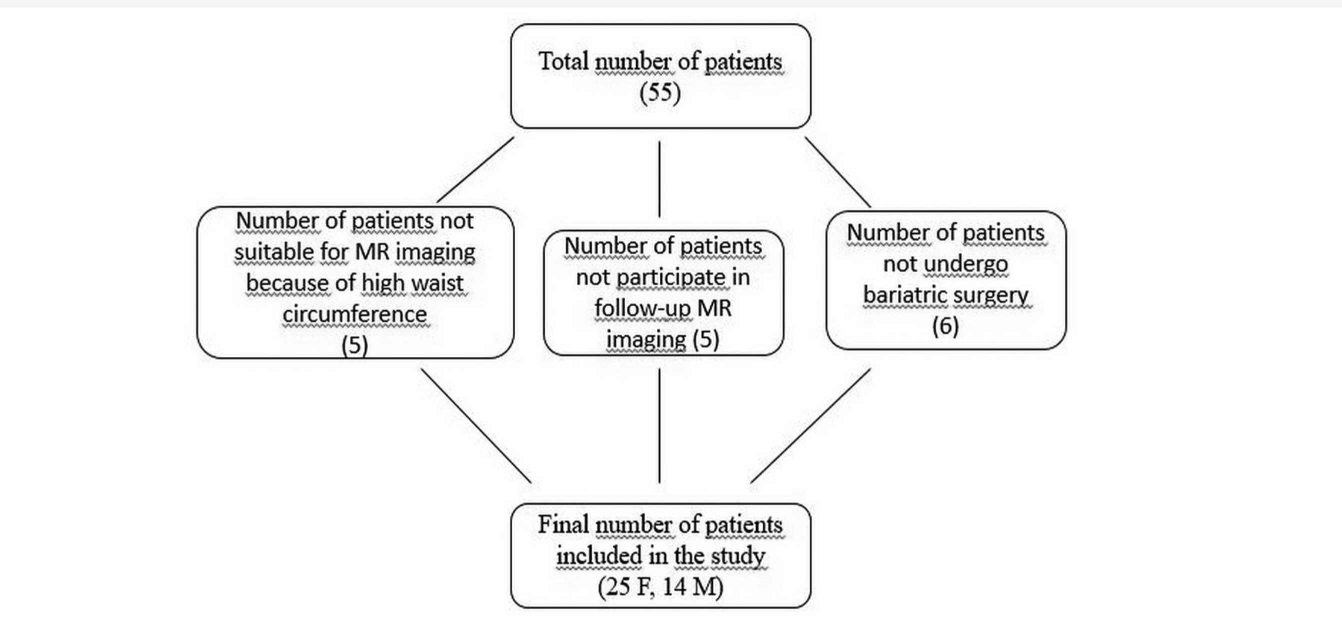

Figure 1. The patient flow diagram is shown

MR: Magnetic resonance, F: Female, M: Male

RESULTS

The present study included 25 female (64.1%) and 14 male (35.9%) patients with a mean age of 41.2±12.5 years.

There was a statistically significant change between preoperative and postoperative values of BW, BMI, LFF, PFF, LL and LV (Table 1).

In the preoperative period, 33 (84.6%) of 39 patients had NAFLD, while 6 patients (15.4%) had no fatty infiltration of liver. Fatty infiltration of liver completely resolved in 26 (66.7%) of 39 patients in the postoperative period, which was statistically significant (p<0.001). In the preoperative period, 16 patients (41%) had NAFPD, and after bariatric surgery, complete resolution of fatty infiltration was observed in 12 (75%) of patients, which was statistically significant (p<0.001). There was a statistically significant decrease in the mean LFF and PFF values in the early postoperative period (p<0.001) (Figure 2). Also, the mean LL and LV values decreased significantly (p<0.001) (Figure 3).

According to the correlation analysis (Table 2), there was a moderate positive linear correlation between LFF and PFF, LL, LV (p<0.001) (Figure 4). A weak positive linear correlation was observed between LFF and BMI (p<0.001), BW (p<0.005).

DISCUSSION

Our study has shown that significant remission is observed in the fatty infiltration of the liver and pancreas in the early period after bariatric surgery, and these positive changes can be detected accurately and non-invasively in a very short time with the ideal IQ sequence.

NAFLD and NAFPD are the diseases that develop due to obesity and, if not treated, can lead to serious health problems in a wide spectrum from infectious processes to malignancy in the liver and pancreas parenchyma[2]. Today, the increasing

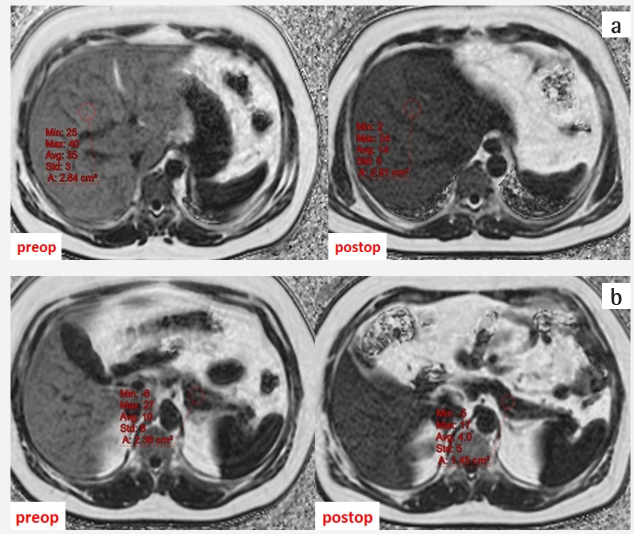

Figure 2. a, b) A 35-year-old male patient undergoing bariatric surgery had a reduction in LFF after surgery by 60% (preop LFF=35%, postop LFF=14%). In the same patient, the pancreatic fat fraction also showed a 60% reduction after surgery. Preop PFF=10%, postop PFF=4%)

LFF: Liver fat fraction

Table 1. Results of variables measured at preoperative and postoperative periods

Parameters	Preoperative	Postoperative	p value
BW (kg)	126.4±20.1 (82-175)	111.5±17.8 (76-155)	<0.001
BMI (kg/m²)	46.0±5.2 (35-65)	40.5±4.9 (33-59)	<0.001
LFF (%)	16.8±10.6 (5-40)	7.1±4.8 (2-20)	<0.001
PFF (%)	9.4±4.7 (3-24)	5.0±4.1 (0-19)	<0.001
LL (mm)	214.4±22.9 (168-267)	193.1±20.3 (156-245)	<0.001
LV (cm³)	2611.7±551.8 (1715-3843)	1949.7±380.9 (1181-2887)	<0.001

BMI: Body mass index, BW: Body weight, LFF: Liver fat fraction, LL: Liver length, LV: Liver volume, PFF: Pancreas fat fraction

Table 2. The correlation analysis between LFF changes and other variables after the bariatric surgery

Parameters	r	R^2	p value
PFF (%)	0.69	0.33	<0.001
LL (mm)	0.61	0.37	<0.001
LV (cm³)	0.49	0.24	<0.001
BMI (kg/m²)	0.34	0.11	<0.001
BW (kg)	0.21	0.04	<0.001

BMI: Body mass index, BW: Body weight, LFF: Liver fat fraction, LL: Liver length, LV: Liver volume, PFF: Pancreas fat fraction frequency of obesity and obesity-related diseases has made the importance of bariatric surgery even more evident. Therefore, demonstrating and monitoring the positive effects of bariatric surgery about the course of NAFLD and NAFPD has also gained great importance. At this point, we aimed to investigate the effects of bariatric surgery on liver and pancreatic fatty infiltration non-invasively by using a novel MRI sequence; ideal IQ (MR-PDFF).

Liver biopsy is the gold standard method used in the determination of the fatty infiltration of the liver and its harmful effects on the liver parenchyma[9,22]. However, this invasive method has disadvantages such as having preprocedural complications including bleeding, allowing sampling only from a specific liver area, operator dependency, and high cost[23]. In addition, this method requires performing a liver biopsy before or during surgery, and will expose the patient to these risks several times in the follow-up period. For this reason, non-invasive radiological imaging methods are used instead of liver biopsy to detect fatty infiltration in visceral organs. In the current study, it was aimed to investigate the effects of bariatric surgery both on liver and pancreatic fatty infiltration with MR-PDFF, which is accepted as the most effective and accurate method in the evaluation of fatty infiltration in recent years. Ideal IQ sequence provides volumetric whole-liver and pancreatic coverage in a single breath-hold and generates estimated T2* and triglyceride fat fraction maps in a non-invasive manner. It was found that the MR-PDFF method showed a high correlation with magnetic resonance spectroscopy (MRS) and liver biopsy in the evaluation of fatty liver[24-26]. Among the advantages of this method, unlike MRS, it does not require special experience for evaluation, and it can be easily measured from any level of the liver parenchyma in a shorter time without the need for postprocessing procedures. As in our study, the amount of fat both in the pancreas and in the liver parenchyma can be quantitatively calculated in seconds with a single sequence.

One of the most important findings in the current study is that fatty infiltration of the liver decreased significantly at the end of first month after bariatric surgery. In 66.7% of the patients participating in our study, after bariatric surgery, LFF values decreased below 6.5% and NAFLD was completely regressed. Unlike other publications in the literature[27,28], in this study, we found that LFF values regressed to normal values in more patients in the early postoperative period. It is thought that two main factors play a role in determining such a significant decrease in LFF of the patients after bariatric surgery. The first reason is that the basal LFF (16.8±10.6%) and BMI (46.0±5.2 kg/m^2) values of the patients who participated in the study were relatively higher than the basal values in other studies. The second reason is that, unlike other studies, our patients were not given very low calorie diet therapy before surgical treatment. In other studies, it was found that patients both showed weight loss and decreased LFF values after an average

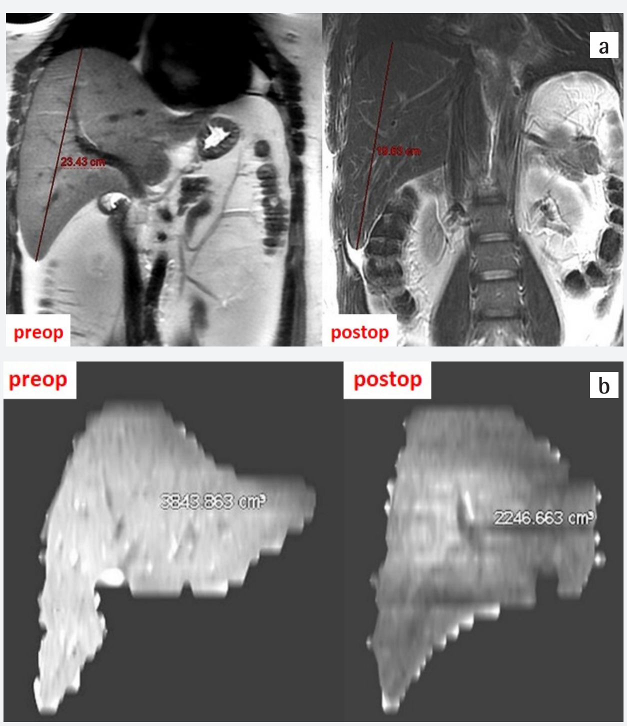

Figure 3 a, b). The patient had a 16% reduction in the craniocaudal LL in the postoperative period (preop LL=234.3 mm, postop LL=196.5 mm). Also in the same patient, there was a 41% reduction in liver volume after bariatric surgery (preop liver volume=3843 cm^3, postop liver volume=2246 cm^3)

LL: Length of the liver

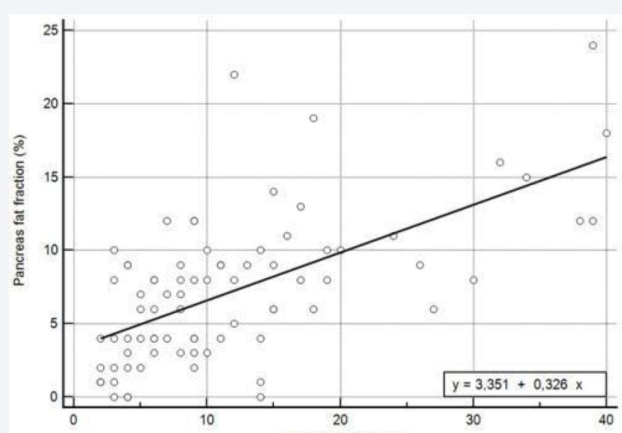

Figure 4. Correlation analyses showed a significant moderate positive linear correlation between LFFs and PFFs (r=0.69; R2=0.33, p<0.001)

LFF: Liver fat fraction, PFF: Pancreas fat fraction of two weeks of low-calorie diet before surgery. This was considered as the reason for less weight loss and decrease in LFF compared to our study. It is thought that not applying a calorie diet to our patients before the surgical treatment causes them to lose weight more quickly and effectively after surgery. However, in order to demonstrate this more clearly, it is considered that future studies will be conducted in which patients who are treated and not treated with diet are evaluated comparatively.

There are limited numbers of publications investigating the effects of bariatric surgery on pancreatic fat infiltration[29,30]. Similar to our study, in most of these publications, a significant decrease in pancreatic FF values was detected after bariatric surgery. In the study of Covarrubias et al.[30], a mean decrease of 0.4% in PDFF values at the 1st month and 5.7% at the end of the 6th month was found after bariatric surgery. In another study by Hui et al.[29], it was stated that there was a 1.6% decrease in PDFF rates at the end of 6 months and 4.5% at the end of one year. Although studies have found a decrease in pancreatic FF values at different rates, it is understood that this decrease continues to increase with time. In our study, it was found that 41% of the patients had pre-operative NAFPD, while 75% of the patients had total regression after surgery. Moreover, it was found that there was a 4.4% decrease in pancreatic PDFF rates in the early postoperative period (1 month after surgery). The higher rate of decrease in FF values in our study was evaluated primarily due to the inclusion of more patients.

Today, the time course of postoperative fat fraction changes in visceral organs is not clearly known. However, most studies report that the positive effects of bariatric surgery on fatty infiltration in visceral organs as well as on anthropometric measurements such as BMI and BW continue long term. Accordingly, it was found that LFF reached normal values in almost all patients at the end of the 12th month. On the other hand, it has been reported in most publications that the most significant reduction in liver and pancreatic fat fraction occurs in the early postoperative period (usually at the end of the 1st month)[27,30,31]. In our study, in parallel with the publications in the literature, a statistically significant decrease was found in the liver and pancreatic fat fraction values of all patients in the first month after surgery. In the study of Luo et al.[27], it is understood that the highest decrease in liver PDFF rates occurred in the 1st month after surgery. In addition, while there was no significant change in liver volume in the following imagings, it was determined that the decrease in liver FF values continued, albeit to a lesser extent. Similarly, in another study conducted by Pooler et al.[31], it was observed that the highest decrease in liver FF rates was detected in the first month postoperative controls (5.6%). On subsequent follow-up imaging, the decrease in liver FF values (2.8% at the end of the 3rd month and 1.6% at the end of the 6-10th month) continued at decreasing rates. On the other hand, it was understood that the fatty infiltration completely resolved in 66.7% of our patients with NAFLD and in 75% of our patients with NAFPD after the bariatric surgery. This was determined as an evidence that the positive effects of bariatric surgery were most evident in the early period.

Study Limitations

Our study has some limitations. Firstly, although relatively few patients were involved in this study, it is among the studies with highest number of patients on the same topic. Secondly, liver biopsy, which is the gold standard method in the diagnosis of fat infiltration, was not performed in the patients in our study because of its invasiveness and difficulty after treatment. Thirdly, since bariatric surgery is a new treatment method that has been started to be used in our center, the long-term effects of the treatment have not been investigated due to the fact that patients did not adapt adequately to follow-up imaging. Fourthly, sleeve gastrectomy was mainly performed on our patients, and other bariatric surgical methods were applied in a limited number of cases. Therefore, the effects of surgical methods on visceral organ fatty infiltration have not been compared. However, it is planned to conduct studies comparing the effects of different bariatric surgery methods on liver and pancreatic fat in the future. Compared to similar studies in the literature, our study is a rare study that includes a larger number of patients and examines the early changes in both liver and pancreatic fatty infiltration caused by bariatric surgery using a non-invasive method. Lastly, to our knowledge, this is the first study on this topic from Eastern Mediterranean region.

CONCLUSION

Ideal IQ sequence is a non-invasive effective method that allows the monitorization of the positive effects of bariatric surgery on liver and pancreatic fatty infiltration.

Ethics

Ethics Committee Approval: This retrospective study was approved by the Recep Tayyip Erdoğan University Institutional Review Board in our institution (decision number: 2019/113, approval date: 09.09.2019).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.K., M.K.Ç., Concept: Y.M., Design: Y.M., Data Collection or Processing: Y.M., N.O.M., F.T., O.Ö., Analysis or Interpretation: A.K., Literature Search: Y.M., N.O.M., O.Ö., Writing: Y.M., N.O.M., O.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

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