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Acoustic radiation force impulse shear wave elastography (ARFI) of acute and chronic pancreatitis and pancreatic tumor

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ABSTRACT

Introduction: Acoustic Radiation Force Impulse (ARFI) elastography evaluates tissue stiffness non-invasively and has rarely been applied to pancreas examinations so far. In a prospective and retrospective analysis, ARFI shear wave velocities of healthy parenchyma, pancreatic lipomatosis, acute and chronic pancreatitis, adenocarcinoma and neuroendocrine tumor (NET) of the pancreas were evaluated and compared.

Material and methods: In 95 patients ARFI elastography of the pancreatic head, and also of the tail for a specific group, was analysed retrospectively. Additionally, prospectively in 100 patients ARFI was performed in the head and tail of the pancreas.

Results: A total of 195 patients were included in the study. Healthy parenchyma (n = 21) and lipomatosis (n = 30) showed similar shear wave velocities of about 1.3 m/s. Acute pancreatitis (n = 35), chronic pancreatitis (n = 53) and adenocarcinoma (n = 52) showed consecutively increasing ARFI values, respectively. NET (n = 4) revealed the highest shear wave velocities amounting to 3.62 m/s. ARFI elastography showed relevant differences between acute pancreatitis and chronic pancreatitis or adenocarcinoma. With a cut-off value of 1.74 m/s for the diagnosis of a malignant disease the sensitivity was 91.1% whereas the specificity amounted to 60.4%.

Conclusion: ARFI shear wave velocities present differences in various pathologies of the pancreas. Acute and chronic pancreatitis as well as neoplastic lesions show high ARFI values. Very high elasticity values may indicate malignant disease of the pancreas. However, there is a considerable overlap between the entities.

1. Introduction

Ultrasound is the most commonly used initial method to evaluate abdominal pain or pathologic laboratory data. Furthermore, it is utilized in screening situations. During transabdominal ultrasound, the pancreas is regularly visualized and abnormalities, such as pancreatic lipomatosis, acute or chronic pancreatitis and pancreatic lesions, can be delineated. In the daily routine, differentiation between early diseases and normal findings is often challenging.

Elastographic ultrasound techniques are suitable to assess elastic properties of a tissue non-invasively. Hard focal pancreatic lesions occurring on elastography during endoscopic ultrasound (EUS) are suspicious for pancreatic carcinoma [1], however differentiation from chronic pancreatitis is not regularly possible [2]. Nevertheless, elastography during EUS can be useful as a complementary tool for early detection of chronic pancreatitis or pancreatic cancer, for the characterization of focal pancreatic lesions and for guiding biopsy in hard areas [3–5]. The peak shear wave elastography Acoustic Radiation Force Impulse (ARFI) cannot be performed by EUS up to now.

The ARFI technique uses transabdominal short-duration acoustic radiation forces to generate localized displacements in tissue. These displacements result in shear-wave propagation away from the region of excitation and are tracked using ultrasonic

Abbreviations: ARFI, acoustic radiation force impulse; AUROC, area under the receiver operating characteristic; BMI, body mass index; CT, computed tomography; ERCP, endoscopic retrograde cholangiopancreaticography; EUS, endoscopic ultrasound; IQR, interquartile range; MRE, magnetic resonance elastography; MRI, magnetic resonance imaging; NET, neuroendocrine tumor; SD, standard deviation.

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correlation-based methods. The tissue response to these acoustic forces can be monitored both spatially and temporally. Displacement magnitude is inversely proportional and shear-wave velocity is directly proportional to local tissue stiffness. A single transducer is used both for applying localized radiation forces within tissue for short time periods and for tracking the resulting tissue displacements. Results are expressed in meters per second (m/s), this shear-wave propagation velocity is proportional to the square root of tissue elasticity.

Recently, studies using the transabdominal approach by ARFI elastography evaluated different abdominal organs [6]. Especially in pancreatic diseases, such as acute, chronic pancreatitis or pancreatic carcinoma, relevant higher shear wave velocities than in healthy pancreas parenchyma are described [7–9].

This study aimed at analyzing the feasibility and performance of ARFI shear wave elastography in various pancreatic diseases, such as pancreatic lipomatosis, acute pancreatitis, chronic pancreatitis and pancreatic masses, respectively. For that purpose, a retrospective and prospective evaluation of pancreatic ARFI data was performed including additively healthy pancreas and neuroendocrine tumors (NET).

2. Material and methods

Between September 2009 and August 2012 pancreas elastography results of healthy organs, acute and chronic pancreatitis, adenocarcinoma and NET of 95 patients were retrospectively analyzed. Then between February 2014 and June 2015 100 patients with hyperechoic pancreas, acute pancreatitis, chronic pancreatitis or pancreatic carcinoma were prospectively enrolled including measurement depth and levels of CRP and lipase. All patients were evaluated for demographic data (age, gender, body mass index (BMI)). The study complies with the ethics guidelines of the Helsinki Declaration and informed consent has been obtained from each patient.

2.1. ARFI measurements

The ultrasound system Acuson S2000 (Siemens Medical Solutions, Erlangen, Germany) was used in the Virtual Touch Tissue Quantification mode to perform an abdominal sonography with ARFI measurements. In the prospective evaluation a region of interest (10×5 mm) was set to the head/corpus area as well as to the corpus/tail of the pancreas during real-time B-mode imaging (Fig. 1a and b). In patients with adenocarcinoma, the lesion and the surrounding parenchyma were assessed by ARFI. In the retrospective analysis, ARFI measurements were recorded only in the head, except for the healthy group in which we evaluated both locations (head and tail). All measurements were conducted in an axial plane from an epigastric position during a relaxed pause in breathing. For the retrospective evaluation an inclusion criterion of at least 4 measurements was applied (by use of transducer 4C1). Within the prospective evaluation process 10 measurements were performed by means of the curved array transducer 6C1HD. Measurements were performed by two experienced operators (DEGUM qualification level 2).

In the prospective group the number of failed measurements ("X.XX" m/s) was recorded.

2.2. Confirmation of diagnosis

Healthy pancreas was assumed due to lack of epigastric symptoms or diarrhea, normal levels of lipase and normal transabdominal ultrasound. Diagnosis of pancreatic lipomatosis was based upon hyperechoic parenchyma on B-mode ultrasound plus evidence of hepatic steatosis (hyperechoic liver compared to the kidney parenchyma, dorsal attenuation and/or blurring vessel borders).

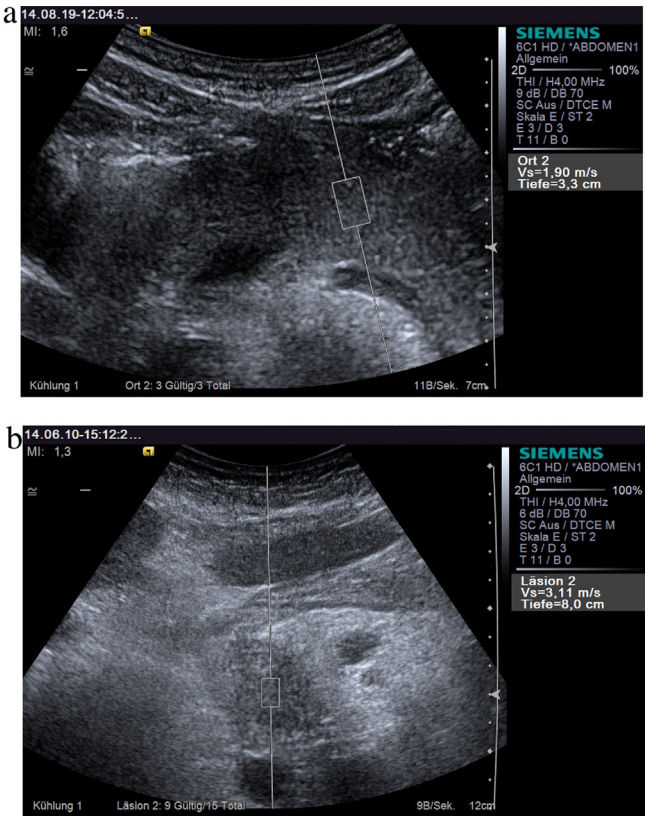

Fig. 1. Axial plane of the epigastric region: measurement of ARFI elastography of a acute pancreatitis in the corpus/tail and b adenocarcinoma in the head of the pancreas.

Patients with acute pancreatitis presented with typical epigastric pain and elevation of lipase (at least 3x the upper limit of normal). Chronic pancreatitis was diagnosed by the medical history and typical abdominal ultrasound findings (irregular pancreatic duct or surface or calcifications) or results of further imaging techniques EUS, magnetic resonance imaging (MRI) or endoscopic retrograde cholangiopancreatography (ERCP), according to general recommendations [10]: pathological side branches, cystic changes, heterogeneous parenchymal structure, calcifications and duct irregularities or strictures. Malignant disease (adenocarcinoma or neuroendocrine carcinoma) has been proved by histopathology in every case.

2.3. Statistical analysis

Clinical and laboratory characteristics of patients as well as the ARFI values were expressed as the mean ± standard deviation (SD) and the range indicated in brackets. The interquartile range (IQR) is a measure of statistical dispersion, expressing the difference between the upper and lower quartiles. The Spearman's correlation coefficient (r) was used for analysis of relationships between variables and the *t*-test to compare means. The results were illustrated in tables or in a boxplot, with median as a thick line passing through each box, which represents interquartile range within which 50% of the values are located. Error bars mark minimum and maximum values (range). Small asterisks mark outliners. For calculation of the cut-off ARFI value the Youden-Index was applied and the diagnostic performance of the area under the receiver operating characteristic (AUROC) was calculated. A p-value <0.05 indicated a significant correlation or difference. All reported p-values are two-sided. Sta-