Original Article

M-mode ultrasound for assessment of the "tethered fat sign" in children: an easily performed way to certify a dynamic process as a still picture

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Background: Omental infarction is a rare pediatric disease. Ultrasound is a useful modality for a non-invasive pre-operative differential diagnosis between inflammatory conditions (as appendicitis) and omental infarction, especially by detecting immobility of the omentum adhered to the abdominal wall ("tetherd fat sign"). However, this is a dynamic sign that cannot be documented in a static image with B-mode technique. The goal of this work is to incorporate the versatile function of motion mode (M-mode) into omental infarction diagnosis to describe how the M-mode is useful in the evaluation of fat motion in children suspected of having omental infarction. In 2019 we suggested a new Ultrasound sign named "tethered fat sign" for an accurate non-invasive diagnosis of omental infarction in children. This finding was observed in 6 of the 234 seen children of our previous study with 4 laparoscopic confirmed diagnosis.

Methods: From January 2019 to July 2021, we evaluated 195 children (91 boys and 104 girls, from 3 to 15 years) admitted to our Santobono-Pausilipon Children Hospital with acute right-sided abdominal pain. Abdominal ultrasound was performed to all the patients and the investigation of "tethered fat sign" was always included.

Results: In 7 patients ultrasound showed the presence of a hyperechoic oval mass localized in the right upper abdominal quadrant and in 2 of these M-mode documented a normal subhepatic fat moving during respiratory movements in relation with the abdominal wall. The remaining 5 patients had an omental infarction showed as a subhepatic motionless mass tethered to the abdominal wall on M-mode. In these patients, a sonographic follow-up was performed every 15 d for 2 months showing a progressive reduction in size of the right-sided hyperechoic mass.

Conclusions: In the evaluation of all children who showed the presence of the "tethered fat sign" the use of M-mode provide a certified image in diagnostic ultrasound.

Keywords: Omental infarction; motion mode (M-mode); ultrasound; omental thickening; tethered fat sign; pediatrics

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Introduction

Ultrasound motion mode (M-mode) or time-motion mode (TM-mode) is a form of ultrasonography with a remarkable axial and temporal resolution of structures that can generate high-frequency sound waves (1 to 7 MHz). It finds wide application to evaluate motion or timing, such as cardiology, pulmonary medicine and emergency medicine (1-3). It provides for the acquisition of echo signal along only one line of the scanning field that is emitted, received, and displayed graphically with the abscissa representing time and the ordinate distance from the transducer. The resultant record is termed a motion, or M-mode, echogram which affords an "ice pick" view of the analyzed structure derived from the time delay from echo emission to reflection and depiction (1).

M-mode sonography (M-mode) has already been used to examine motion in respiratory excursions (4), but its use has never been reported in children to assess "motionless fat". We suggest the use of M-mode as supplementation of brightness mode (B-mode) ultrasonography in the pediatric evaluation of the "tethered fat sign" in suspicion of right side segmental infarction of the omentum, an infrequent cause of acute abdominal pain in children with usually not specific symptoms (5). Omental infarction consists in a hyperechoic subhepatic mass tethered to the abdominal wall which is motionless during respiratory excursions (6).

This work aims to describe how the M-mode is useful in the evaluation of fat motion in children suspected of having omental infarction.

Methods

This study was performed in accordance with the ethical standards and the Declaration of Helsinki (as revised in 2013). The study was approved by our regional ethic committee of "Campania Region" (approval No. 9/23 OSS-SP) and informed consent was taken from the parents of all the patients.

Two skilled pediatrics radiologists F.E. and D.N. with over 15 years of experience assessing the high-resolution US images of a total of 195 children (91 boys and 104 girls from 3 to 15 years) with non-specific acute/subacute abdominal pain that mostly involves the right-sided abdominal quadrants, admitted to Santobono-Pausilipon Children's Hospital with a presumptive diagnosis of acute appendicitis from January 2019 to July 2021. In all patients the investigation of the "tethered fat sign" was included and the US examination was performed using convex (3–6 MHz) and linear transducers (7.5–18 MHz) (GE Logiq E9, GE, Milwaukee, WI, USA) (Esaote MyLab 9, Genova, Italy).

In 188 patients, the omental fat resulted to be normal or hyperechogenic, not tethered, and other causes of abdominal pain were diagnosed (as urolithiasis, pancreatitis, etc.). Of the remaining 7 children (4 boys and 3 girls, from 5 to 14 years), 2 showed fever and all of them nausea and vomiting with peritoneal signs and tenderness. In 5 children, we observed a high weight for their age (body mass index >25 kg/m^2). Blood exams were in the normal range or presented a slight leukocytosis and elevation of C-reactive protein.

We used higher and lower frequencies focusing the beam immediately below the area of interest. After a classic B-mode abdominal US examination, Color and power Doppler imaging was employed to assess flow signals and also the "tethered fat sign" was analyzed (5); a supplemental M-mode imaging assessment in addition to traditional B-mode ultrasonography was used to image irregular fat movement. The M-mode line was placed at the thickest point of the hyperechogenic subhepatic mass, providing a single image as documentation of "motionless fat". Finally, we widely explored all the appropriate lymphatic stations to evaluate the occurrence of pathological not inflammatory lymph nodes (hypoechoic round or oval nodes as well as lymph node with preserved fatty hilum, but increased (>3 mm) diffuse or asymmetric cortical thickness) which should be mandatory in any case of noncompressible mass (7).

Results

In 7 patients, we found a hyperechoic uncompressible mass in the right upper abdominal quadrant, between the anterior abdominal wall and the ascending or transverse colon, suggesting a possible omental infarction diagnosis (*Figure 1*) (8). Therefore, the investigation of the presence of the "tethered fat sign" was performed, and, after that, M-mode assessment was included in all of them.

In 2 patients, M-mode documented normal subhepatic fat moves during respiratory movements in relation to the abdominal wall: the "sliding fat sign" (*Figure 2*, Video S1). In case of subhepatic acute appendicitis the identification of a hyperechoic non-compressible mass can be made similarly to omental infarction. For them, in fact, a diagnosis of subhepatic acute appendicitis was confirmed due the presence of its sonographic features (*Figure 3*,

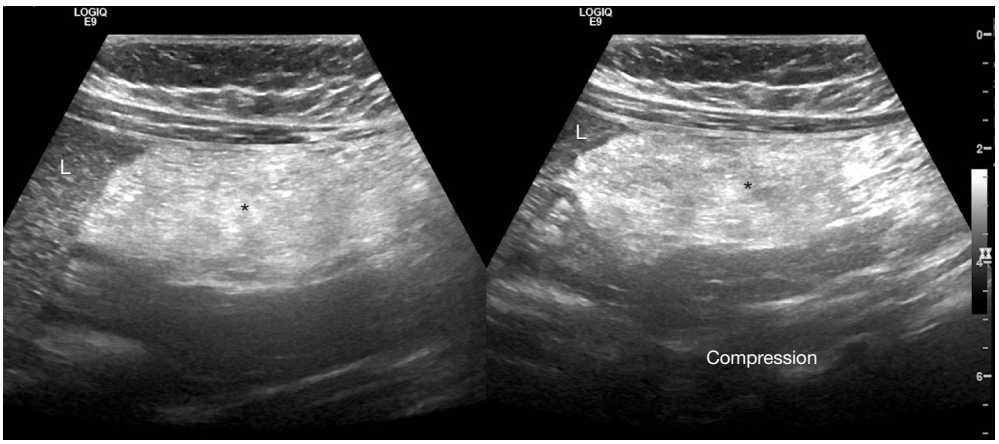

Figure 1 B-Mode examination in omental infarction. Hyperechoic, incompressible, oval mass (indicated by *) of 51×20.9 mm located in the upper right abdominal quadrant, below the lower hepatic border, just behind the anterior abdominal wall. L, liver.

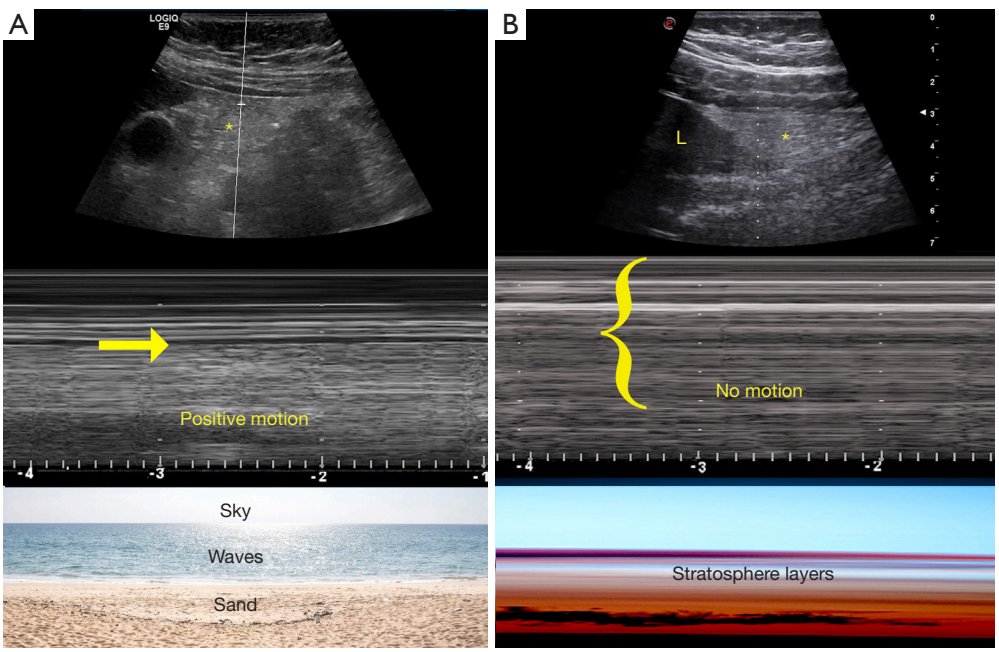

Figure 2 M-mode image is used to record the presence or absence of fat sliding when cine-loops storage is not available. Herein are the two possible patterns. (A) Normal “sliding fat sign”. A normal subhepatic fat moves during respiratory movements in relation to the abdominal wall. This M-mode picture demonstrates a linear, laminar pattern in the superficial tissue (“sky” and “waves”) and a granular (“sandy”) appearance corresponding to omental fat. This phenomenon is already known as the “seashore sign”, used for the investigation of lung sliding. The transition between “waves” and “sand” represents where sliding is detected in M-mode (yellow arrow). Normal sliding fat (*). (B) Pathologic “tethered fat sign”. A subhepatic mass is tethered to the abdominal wall and then displayed motionless on M-mode. The M-mode picture demonstrates a linear, laminar pattern in both superficial tissue and omental fat. This phenomenon is already known as the “stratosphere sign” or “barcode sign” ({). It confirms the omental infarction of diagnosis tethered fat (*). L, liver; M-mode, motion mode.

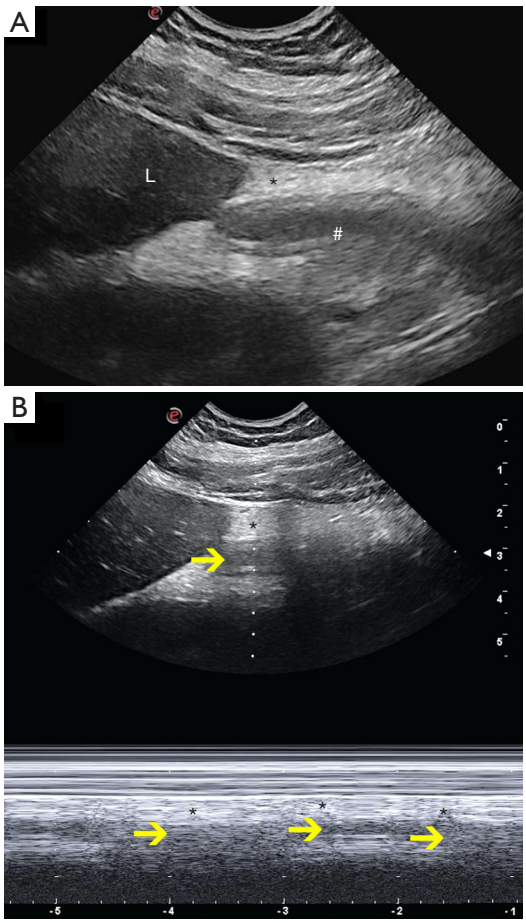

Figure 3 These images documented a normal subhepatic fat moving in during respiratory movements in relation to the abdominal wall (the "sliding fat sign") in the context of a subhepatic acute appendicitis. (A) B-mode view of a subhepatic acute appendicitis. (B) M-mode in the same patient. Inflamed appendix (yellow arrows). #, appendix; *, hyperechoic omental fat. L, liver; B-mode, brightness mode; M-mode, motion mode.

Video S2) (9).

All remaining 5 patients had an omental infarction. They showed a subhepatic mass tethered to the abdominal wall that resulted in motionless on M-mode (*Figures 2B,4A,4B*) (Videos S3,S4). Only 1 child underwent surgery confirming the diagnosis of omental infarction. Four patients received a conservative treatment because we found the "tethered fat sign" (that we certificate as a still image with the support of M-mode) and a moderate symptomatology (10). A clinical and sonographic follow-up was performed every 15 for 2 months, showing a progressive reduction in the size of the right-sided hyperechoic mass (*Figures 5,6*).

Discussion

This article describes our experience as a single emergency Department with the use of M-mode imaging assessment for suspicion of omental infarction in the children population. It includes the largest pediatric group for which a prospective evaluation could be done in the last two years.

B-mode examination of children with acute abdominal pain represents a recognized tool because it is largely available, easily performed and it avoids the use of ionizing radiations. M-mode is not routinely recommended but may be added in specific cases like the documentation of the immovable structures into omental infarction diagnosis. We believe that M-mode may be useful to document what otherwise will remain undocumented with traditional B-mode ultrasonography, yet M mode (M stands for movement), is nothing more than a "refreshed" B-mode at short enough time span to reproduce the movement of the interface. It does not need skilled pediatric radiologists or expertise in Doppler imaging.

M-mode evaluation of omental tissue can be performed using a similar technique to those described by Epelman *et al.* (4) and Urvoas *et al.* (11).

During the breath, the normal fat tissue moves cranio-caudally toward the transducer. This phenomenon, on an M-mode image, will demonstrate a linear, laminar pattern in the superficial tissue and a granular or "sandy" appearance deeper, showing the characteristic "seashore sign" (already known for pneumothorax evaluation). In omental infarction, the "adipose mass" is anchored to the abdominal wall. Normally the greater omentum is free of any attachment on three sides (inferior, right, and left), so is highly mobile. This mobility predisposes the omentum to torsion, and subsequently, to infarction as a result of compromised perfusion to the greater omentum. When this event occurs, the compromised arteries cause necrosis of the affected part, which, if untreated, will form a fibrous mass surrounded by adhesions to the close abdominal wall, as showed on laparoscopic examination (5). Such immobility will be express as a "barcode\stratosphere sign", which is an upward motion of the M-mode tracing (*Figures 2,4*). In this case, the M-mode image will demonstrate a linear, laminar pattern in the superficial tissue and a similar linear pattern corresponding to the omental area. This second phenomenon, known as the "stratosphere sign" or "barcode sign" confirms the presence of infarction (12).

That's how M-mode record the presence or absence of sliding when store cine-loops will be not possible.

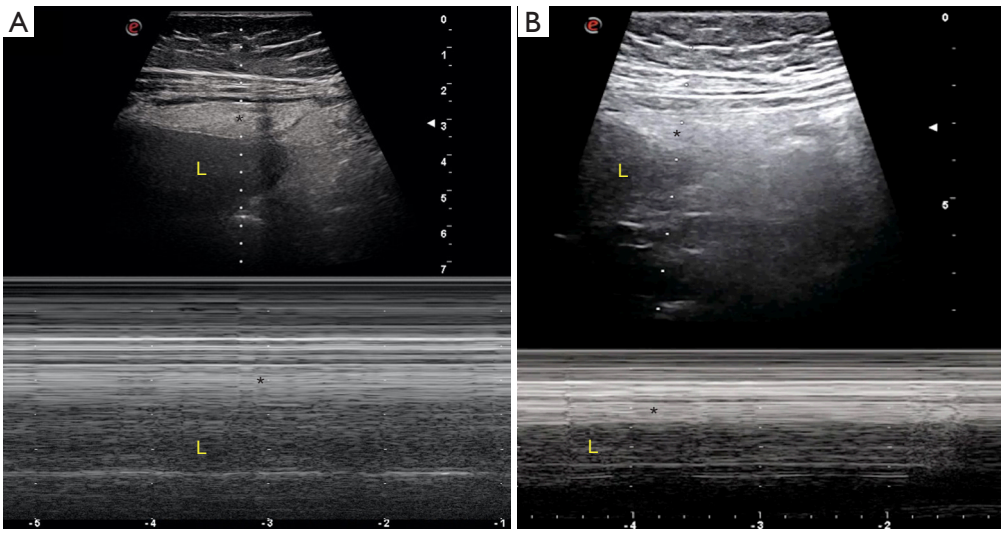

Figure 4 Other 2 examples of omental infarction on M-mode examination. The stratosphere or barcode sign is present in both cases. *, omental infarction. L, liver; M-mode, motion mode.

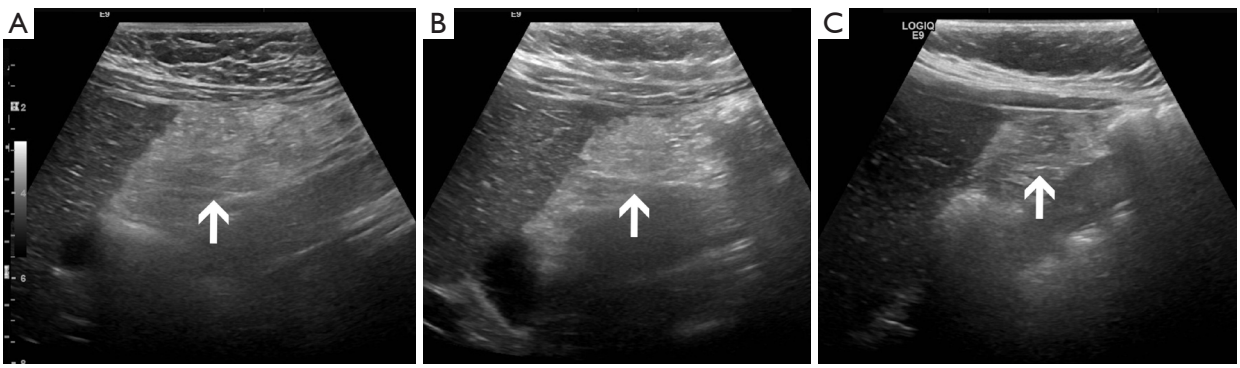

Figure 5 B-mode examination in omental infarction (A) and sonographic follow-ups after 15 (B) and 30 (C) days. The hyperechoic, incompressible, oval mass (arrows) showed a progressive reduction in size and echogenicity after conservative treatment. B-mode, brightness mode.

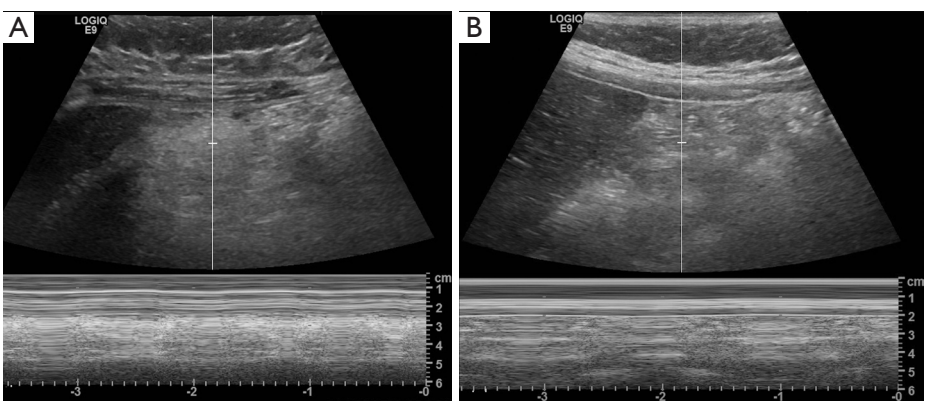

Figure 6 M-mode follow-up examination after 15 (A) and 30 (B) days in the same patient in *Figure 5*. There was a progressive improvement of focal omental fat mobility, as shown in both images and documented as a still picture. M-mode, motion mode.

Even if computed tomography (CT) remains the rule if symptoms persist or in case of nonconclusive findings on US (6), none of our patients underwent CT. That's because a wealth of information may be obtained with M-mode imaging in a simple way. The pediatric radiologist or other point-of-care ultrasound providers can use this modality in the evaluation of young patients for suspected omental infarction.

In our work the radiologists were not blinded to patients clinical and other imaging information; consequently, it was not possible to define the inter-observer variability. In addition, the low number of cases due to the nature of this rare condition, particularly of those exhibiting our "tethered fat sign" and, consequently, on which the M-mode was performed, requires a more consistent number of patients to be validated but, to the best of our knowledge, this is the first readily available and easy-to-use imaging technique to provide diagnosis or differential diagnosis of this etiology, and, to date, it has been observed in all our patients.

Therefore, we hope that our work, despite its limitations, will encourage the use of this modality in diagnostic imaging.

Conclusions

M-mode is a suitable and versatile supplement to traditional B-mode ultrasonography that may easily document a dynamic process as a still image. Obese children with acute pain in the right abdominal quadrant, pauci-symptomatic or not, the possibility of omental infarction should be kept in mind. In patients with suspicion of omental infarction the presence of the "tethered fat sign" should be always ascertained. Nevertheless, the evaluation of "motionless fat" requires a certified image to ensure a confirmed and recognized diagnosis that provides all needed information for the appropriate decision-making process.

Our work suggests that M-mode may aid a non-invasive pre-operative diagnosis, with its suggestive findings and ease of execution, which every radiologist should apply.

Acknowledgments

The image used to show the stratosphere sign originally appeared in the NASA Earth Observatory story "Smoke in the Stratosphere". Astronaut photograph ISS062-E-5419 was acquired on February 12, 2020, with a Nikon D5 digital camera using a 400-millimeter lens and is provided by the ISS Crew Earth Observations Facility and the Earth Science and Remote Sensing Unit, Johnson Space Center. The image was taken by a member of the Expedition 61 crew. Therefore, NASA should be acknowledged as the source of the material.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1691/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by our regional ethic committee of "Campania Region" (approval No. 9/23 OSS-SP) and informed consent was taken from the parents of all the patients.

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