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Double aorta artifact in sonography – a diagnostic challenge

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ultrasound, artifacts, child, duplication artifact, acoustic prism

Abstract

The double aorta artifact was described and studied thoroughly twenty-five years ago. Despite this, it is still not commonly known today and can cause diagnostic difficulty. Total aortic duplication can be considered an anatomic defect whilst partial duplication mimics aortic dissection. In the literature, this artifact has been compared with a very rare anomaly, i.e. the occurrence of two aortas in one patient. Currently, however, the differentiation of this artifact from abdominal aortic dissection seems to be of greater significance. The double aorta image occurs when ultrasound waves encounter prismatic fat tissue of the anterior abdominal wall. This artifact is more frequently observed in children and athletic young adults since the structure of this anatomic region in these individuals is conductive to the occurrence of this phenomenon. Moreover, it can be observed more often when curved transducers are used. Due to all these factors, an ultrasound beam undergoes greater refraction and make the artifact clearer. This phenomenon is usually easily recognizable and avoidable, but it sometimes might cause diagnostic difficulty. Obtaining an image of double abdominal vessels on ultrasound examination in transverse sections requires further inspection of the aorta in a different (sagittal) plane. This is not always possible due to poor patient preparation for scanning. Symmetrical flow on Doppler sonography is a typical feature of this artifact. Finally, magnetic resonance imaging or computed tomography can be considered to rule out a pathology.

Introduction

Hardly any imaging modality, apart from sonography, is characterized by the occurrence of such a variety of artifacts. Their detection and appropriate interpretation depend on the experience of an ultrasonographer. Artifacts are echoes that do not correspond to any anatomic structure. They originate due to assumptions needed to process an ultrasonic signal, such as:

- ultrasound velocity is the same in all organs and structures;
- these impulses scatter in one direction only, along a straight line (and are not refracted);
- a transducer emits extremely short ultrasonic impulses;
- a slight portion of an ultrasound beam is reflected/scattered on each border surface;
- reflected ultrasounds return to the transducer without further reflection (directly).

However, the aortic duplication artifact occurs when the above assumptions are not met. The following facts are crucial for the discussed subject:

- individual tissues conduct ultrasounds with different velocities;
- transducer-emitted impulses and returning echoes are refracted on the border of neighboring tissues (they do not scatter along one straight line)[(1)].

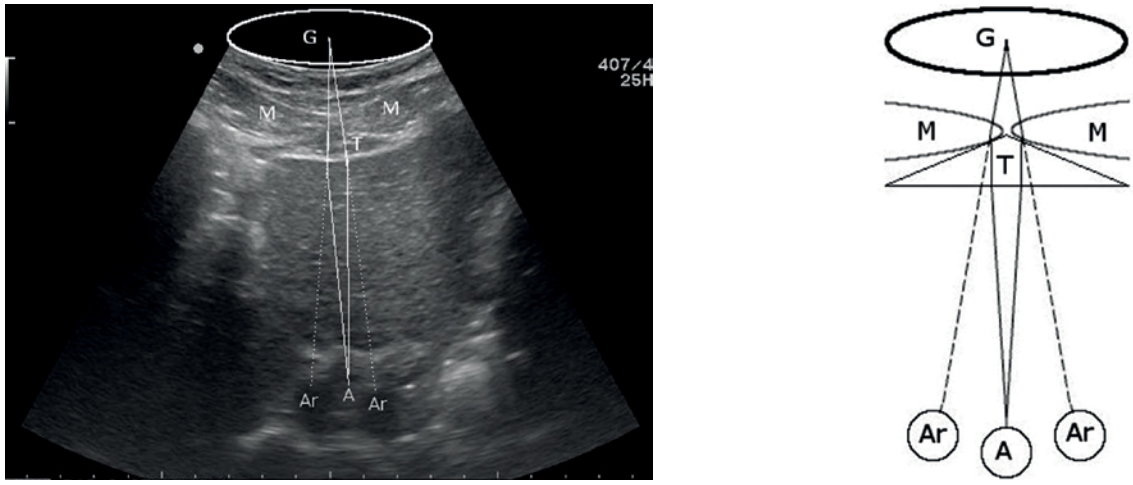

Fig. 1. *A beam (continuous line) sent by the transducer (G) crosses the superficial fat tissue and rectus abdominis muscle (M), and refracts medially on prismatic slow-conductive deep fat tissue (T). The base of the prism is made by the edge of the liver. Subsequently, ultrasounds reach the aorta (A) through soft tissues. Produced echoes undergo identical refraction (continuous line) on their way back to the probe. The monitor shows two vessels (Ar). They are located on a straight line created by the emitted beam (dashed/dotted line)* [1,4,11]*. They are observed to the left and right from the medially situated genuine aorta (A). Duplication concerns not only the aorta, but also all structures located on the way of ultrasounds undergoing refraction. This image is clearer distally from the probe since alleged images are then separated by a greater distance. An abnormal presentation of the margin of the vertebral body located behind the aorta (visible from below) frequently confirms the presence of the artifact rather than genuine duplication*[3]

A very rare congenital disorder or a frequent ultrasound artifact?

An ultrasound image of double aorta is usually an artifact. However, it might raise questions about the origin of congenital aortic anomalies. In an embryo, two dorsal aortas combine into one vessel at week 4. Developmental disorders at that time could result in the occurrence of two large arteries, one next to the other[2]. To date, only two post-mortem cases have been described in the literature where the occurrence of two aortas was suspected[3,4]. These are reports from 1975–1977. The first one presents the coexistence of two completely separate vessels from the level of the ductus arteriosus to the aortic bifurcation. One of these vessels dominated in the visceral bed and the other had only slight branches. This anomaly was clinically asymptomatic[5]. The other case involved duplication of the entire descending aorta. It was accompanied by renovascular hypertension caused by anomalies of the renal arteries originating from both vessels[6]. An article published in 2009 questioned these two cases. Its authors suggest that the second aorta could in fact be persistent umbilical artery[7]. Based on available literature, it can be surely stated that an accessory vessel with an analogous course to the aorta occurs extremely rarely. If consistent flow is detected in two adjacent or even overlapping abdominal vessels, one should consider the quite frequent double aorta artifact in the first place[3,4].

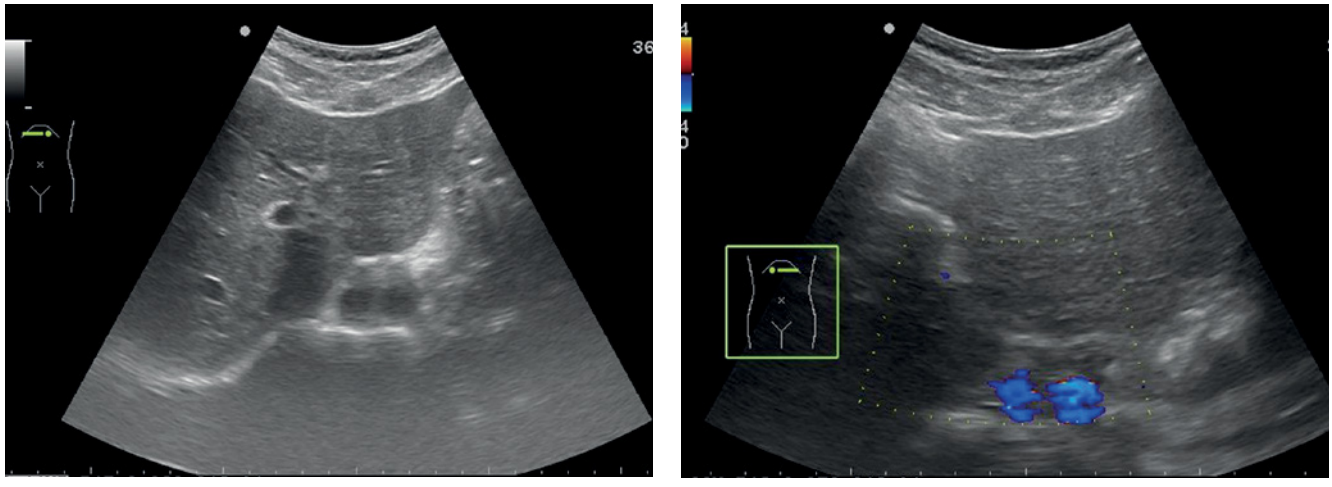

Fig. 2. *Complete aortic duplication in the suprarenal fragment. Doppler scans show consistent flows in both vessels*

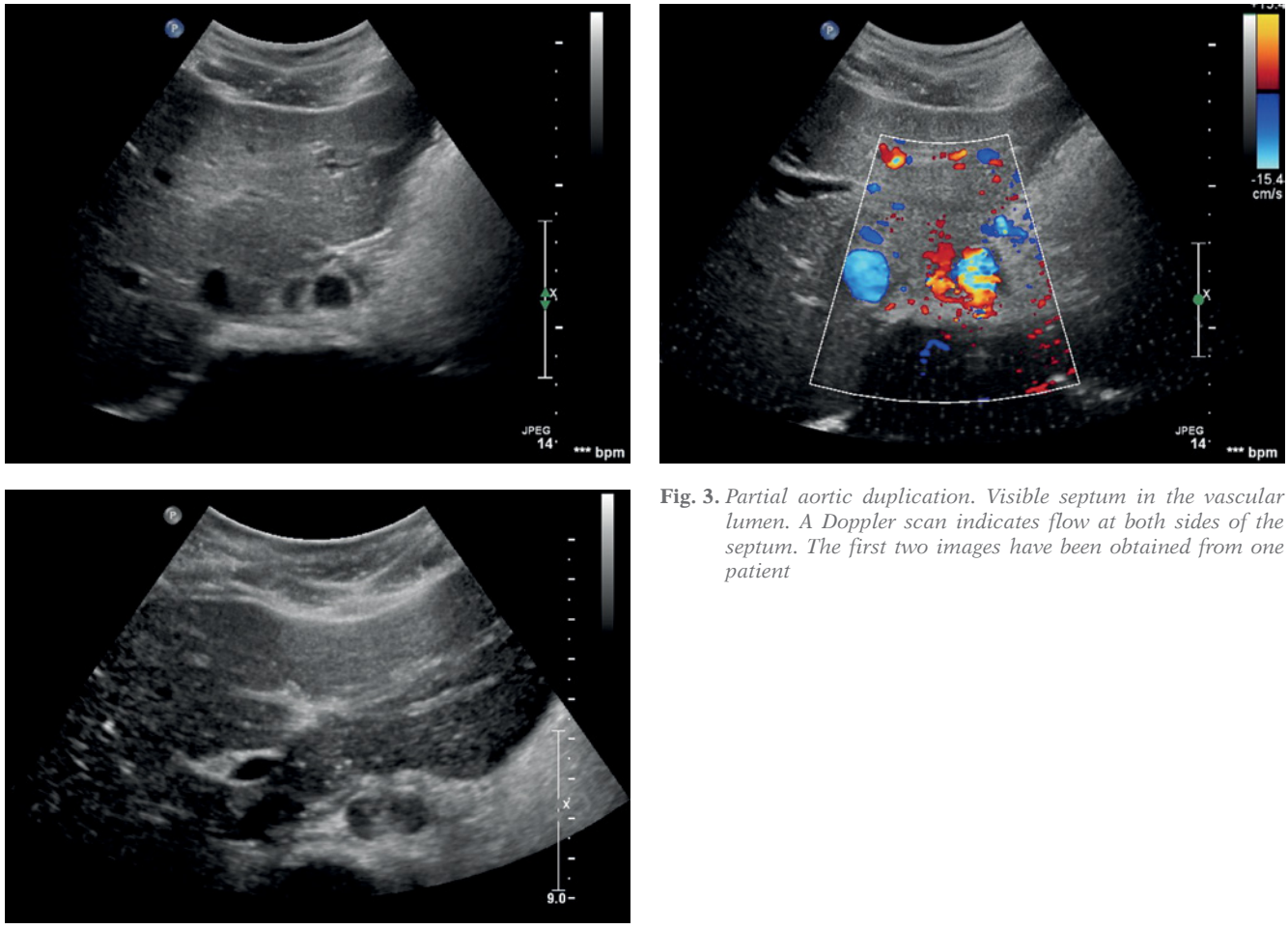

Fig. 3. *Partial aortic duplication. Visible septum in the vascular lumen. A Doppler scan indicates flow at both sides of the septum. The first two images have been obtained from one patient*

Differentiation with a pathology of large abdominal vessels

The literature is relatively poor in reports on the differential diagnosis of the aortic duplication artifact. Nonetheless, the possibility that this artifact might mimic other pathological entities within the region of the abdominal aorta must be taken into account. Differential diagnosis should primarily include aortic aneurysm and dissection due to the frequency of their occurrence. In these cases, Doppler scanning shows double, usually asymmetrical flow through the altered aorta. Moreover, clots frequently develop in the false lumen, and dissection extends to arteries branching off the aorta at the level of the pathology. Abnormal wall structure and asymmetrical shape of a dissecting aneurysm distinguish this pathology from sonographic aortic duplication. The artifact with partial aortic duplication is characterized by normal wall structure and symmetrical flows[8]. In both cases, one might observe a septum within the aortic lumen, which, in aneurysm, originates from the separated intima media, and in the artifact – from ultrasound beam refraction. The paraaortic region might also exhibit dilated or atypically located vessels. Moreover, differential diagnosis should also involve: dilated left testicular vein, duplication of the inferior vena cava, inferior mesenteric vein and dilated left ureter[9].

Mechanism of artifact formation

An ultrasound image of double aorta occurs when an ultrasound beam is refracted in an adequate way from abdominal wall structures. The rectus abdominis muscles and fat tissue between them can create an acoustic prism that refracts ultrasounds[3,4,10,11]. This phenomenon was studied and described in 1990 by Vandeman, but it is still not commonly known and can cause diagnostic difficulty to less experienced ultrasonographers. This artifact more frequently occurs in young athletic individuals[3,11]. Refraction occurs at the border of centers with different acoustic properties (Snell's law: $\sin \alpha_2 / \sin \alpha_1 = V_2 / V_1$). The greater the speed of sound between tissues, the greater the refraction of an ultrasound beam. Ultrasound wave refraction creates an image of the viewed structure in a false location (Fig. 1). The greater the refraction, the further the false aortas are located from each other[4]. That is why greater probe curvature is conductive to the occurrence of the artifact. Authors argue that both the triangular shape of fat deposits between the rectus abdominis bellies and the neighborhood of tissues characterized by considerable conduction speed differences (muscles and fat) affect the occurrence of this artifact[3,4]. In an *in vitro* test and literature review concerning computed tomography performed in 100 patients, deep deposition

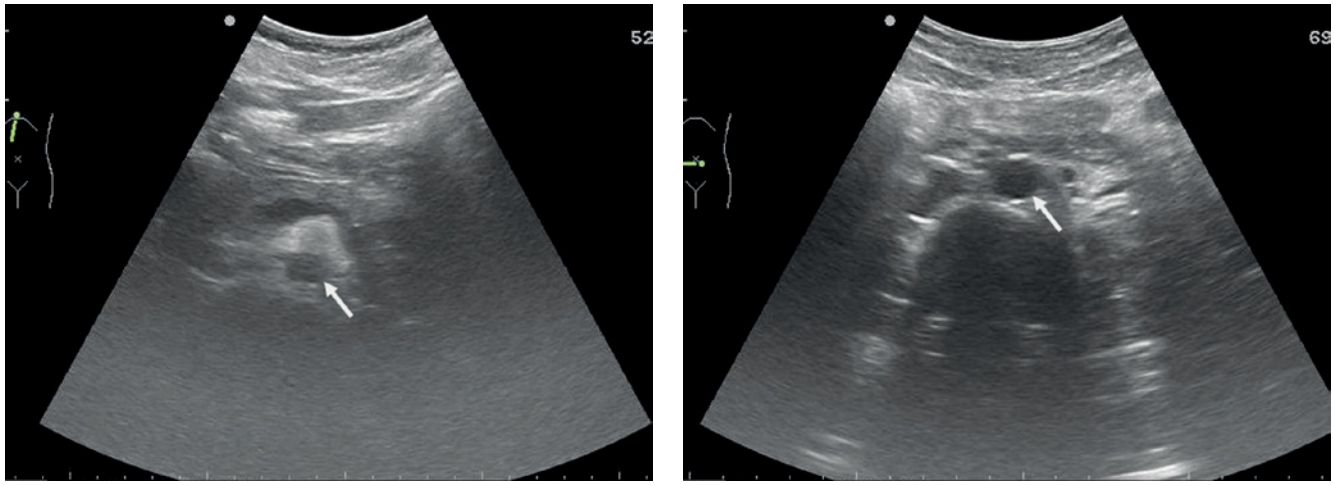

Fig. 4. *Images of the single aorta (white arrow) in the epigastric and hypogastric regions rule out aortic duplication and confirm the presence of the artifact. Both images have been obtained from the same patient as above (Fig. 2).*

of fat tissue was believed to have the greatest impact on the occurrence of the artifact. Superficial fat and muscles play a lesser role. A prismatic shape of a fat deposit makes waves entering from both its left and right sides refract towards the center. Subsequently, they run convergently and reach the aorta from both sides[11]. Returning echoes undergo the same refraction and reach the receiver. The scanner analyzes returning signals as if the echo appeared in the structures located along one straight line from a beam sent by the transducer. This is how an image of two aortas is formed (Fig. 1)[1,4,11].

Artifact recognition and avoidance

The double aorta artifact can appear in both pediatric patients and adults. The type of abdominal wall structure that is not conductive to duplication artifacts is observed in 60–95% of individuals, depending on the body region. These individuals have too small rectus abdominis muscles or they are separated by connective tissue bands, thereby preventing appropriate ultrasound wave refraction. In younger and more muscular patients, the rectus abdominis muscles are larger and give the adjacent fat tissue a prismatic shape. Such a structure is found in the upper part of the abdominal wall in 40% of patients who present this artifact, in the central abdominal wall – in 5% of cases, and in the lower part of the abdominal wall – in 36% of cases[11]. In some patients, aortic duplication is observed only along a certain fragment rather than along its entire course. A Doppler examination of the walls of both vessels is normal and presents identical and consistent flow (Fig. 2). Partial duplication is observed more frequently than total[3].

A cross-section along the midline shows the aorta with a septum or wall between the vascular lumina[4], or with echogenic material (Fig. 3)[10].

This artifact can be avoided by moving the probe laterally from the midline to the right or left and rotating it 90° to the sagittal position[11]. When the image of the abdominal aorta still cannot be obtained, other probe positions, enabling its assessment, should be applied. Lateral probe application (where the kidney forms an acoustic window for the aorta) and the right or left lateral position improve aorta imaging conditions in certain patients. In these cases, the impact of intermuscular fat is avoided. Also, a transducer of lower curvature (a linear probe) can be applied. Certain diagnostic difficulty might occur when aorta inspection using a different position of the probe is restricted[3]. The most frequently described obstacle is gas in the intestinal loops which prevents ultrasound beam conduction. Moreover, segmental occurrence can be another hint enabling recognition of the double aorta artifact. Duplication is not usually seen in aorta fragments running above or below the alleged anomaly (Fig. 4). The symmetrical nature of branches originating from the aorta can also suggest the existence of the artifact; for example, symmetrical origin of the celiac arteries from both aortas, which form one common vascular arch. All vessels present consistent flows in Doppler scanning[4]. Furthermore, a partially duplicated image of the margin of the vertebral body located behind the aorta and distortion of the image of structures located between the probe and aorta confirm the presence of the artifact[3]. Additionally, there are techniques of ultrasound image computer modification, enabling one to obtain images that are free from distortion. For instance, there is a technique which, based on tissue properties, changes probe parameters so as to eliminate undesired impact on the image[12].

Conclusion

An ultrasound image is modified by anatomic structures on the way of an ultrasonic wave to the reflection surface. Refraction can be affected by the following factors: reciprocal tissue position, their shape and density as well as capability of scattering ultrasound waves. They can induce a number of artifacts, thereby leading to diagnostic pitfalls[4]. Apart from the artifact discussed above, other false duplication images resulting from the presence of an ana-

tomic acoustic prism have been noted in sonography. For example, in abdominal scans of women in early pregnancy, the image of a single gestational sac can appear double and be misinterpreted as a multiple pregnancy. This phenomenon can also cause false appearance of two intrauterine devices instead of one[1]. Vascular image duplication or the appearance of a septum in their lumina within the area of the midline in transverse planes should be suggestive of the duplication artifact. In order to rule it out, it is sufficient to re-examine the doubtful aortic fragment from a different probe position, which, however, might be prevented by certain factors, such as gas in the intestinal loops[10]. In such a situation, one should consider abdominal MRI[10] or CT[3,4,11] in order to exclude aortic anomaly. Moreover, existing ultrasound image modification technologies can be useful in correcting the aortic duplication artifact[12].

Conflict of interests

Authors do not report any financial or personal links with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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