

"To-and-fro" waveform in the diagnosis of arterial pseudoaneurysms

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Abstract

Medical ultrasound imaging with Doppler plays an essential role in the diagnosis of vascular disease. This study intended to review the clinical use of "to-and-fro" waveform at duplex Doppler ultrasonography (DDU) in the diagnosis of pseudoaneurysms in the arterial vessels of upper and lower extremities, abdominal aorta, carotid and vertebral arteries as well as to review our personal experiences of "to-and-fro" waveform at DDU also. After receiving institutional review board approval, an inclusive literature review was carried out in order to review the scientific foundation of "to-and-fro" waveform at DDU and its clinical use in the diagnosis of pseudoaneurysms in various arterial vessels. Articles published in the English language between 2000 and 2013 were evaluated in this review study. Pseudoaneurysms in arterial vessels of the upper and lower extremities, abdominal aorta, carotid and vertebral arteries characterized by an extraluminal pattern of blood flow, which shows variable echogenicity, interval complexity, and "to-and-fro" flow pattern on color Doppler ultrasonography. In these arterial vessels, Duplex ultrasonography can demonstrate the degree of clotting, pseudoaneurysm communication, the blood flow patterns and velocities. Spectral Doppler applied to pseudoaneurysms lumen revealed systolic and diastolic turbulent blood flow with traditional "to-and-fro" waveform in the communicating channel. Accurate diagnosis of pseudoaneurysm by spectral Doppler is based on the documentation of the "to-and-fro" waveform. The size of pseudoaneurysm determines the appropriate treatment approach as surgical or conservative.

Key words: Pseudoaneurysm; To-and-fro waveform; Ultrasonography; Percutaneous thrombin injection; Yin-Yang sign

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Core tip: A review of the clinical use of “to-and-fro” waveform at duplex Doppler ultrasonography (DDU) in the diagnosis of pseudoaneurysms in the arterial vessels of upper and lower extremities, abdominal aorta, carotid and vertebral arteries as well as to review our personal experiences of “to-and-fro” waveform at DDU also.

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INTRODUCTION

A pseudoaneurysm is defined as an arterial wall deficiency, which leads to accumulation of oxygenated blood in the nearby extra-luminal region. Therefore arterial blood spread out of the vessel, forming a sac surrounding by soft tissue and compressed thrombus^[1]. Consequently, a pseudoaneurysm is formed as a result of fibrin wall formation nearby the swelling^[2]. The basic difference of arterial aneurysm and pseudoaneurysm is that the three-layers of the arterial wall don't bind the later one^[3]. Pseudoaneurysms which are the most common in the femoral and radial arteries, often noticed in the groin and forearm after cardiac catheterization. Furthermore, it may observe also after arterial punctures of blood gas analysis, after the placement of indwelling catheter or after direct arterial trauma^[2-5].

Ultrasonography (US) has been widely utilized as a noninvasive imaging modality for the investigation of vascular diseases^[6-9]. US which is a valuable tool for diagnosis of pseudoaneurysms has been widely utilized as a noninvasive imaging modality for investigation of vascular disease. The main advantage of US imaging is no use of ionizing radiation, cheap, and availability^[10,11]. It has been reported that US has 94% and 97% of sensitivity and specificity, respectively in the diagnosis of postcatheterization pseudoaneurysms, but this sensitivity is not enough to diagnose the pseudoaneurysms of the deep visceral arteries^[12,13]. The major limitation of US it is an operator dependent imaging technique, has low sensitivity in the evaluation of deep visceral artery pseudoaneurysm, and evaluation of vessels in trauma patient accompanied with hematoma or fracture^[14].

In pseudoaneurysms, Analog US images (grayscale) usually illustrate hypoechoic cystic structures nearby a supplying artery^[15,16]. Grayscale can be used to evaluate many pseudoaneurysmal findings such as the size, the number of pseudoaneurysm, and its relation to the artery^[17]. However, grayscale is not a conclusive evidence in diagnosis pseudoaneurysm because its findings are accompanied by other clinical conditions such as hematomas and cystic masses either simple or

complex^[1].

Therefore, Doppler US can be used to confirm the diagnosis. In addition to that, blood flow in a cystic structure distinguished by swirling motion pattern “yin-yang sign”. Also, this type of flow can be detected in saccular aneurysm. Therefore, differential diagnosis is essential for pseudoaneurysm. The cornerstone of pseudoaneurysm diagnosis is dependent upon the appearance of the communicating neck between the arterial vessel and pseudoaneurysmal sac with “to-and-fro” waveform at duplex Doppler ultrasonography (DDU). The “to” represents the arterial blood going into the pseudoaneurysmal sac in systolic cycle, while “fro” illustrate blood exiting the sac in diastolic cycle^[18].

In this article authors review the clinical use of “to-and-fro” waveform at DDU in the diagnosis of pseudoaneurysms in various arterial vessels, as well as our personal experiences of “to-and-fro” waveform at DDU in the Radiology Department of King Fahad Medical City (KFMC) at Riyadh, Saudi Arabia.

LITERATURE SEARCH

After receiving institutional review board approval, an inclusive literature review was carried out in order to review the scientific foundation of “to-and-fro” waveform at DDU and its clinical use in the diagnosis of pseudoaneurysms in various arterial vessels of the upper and lower extremities, abdominal Aorta, carotid arteries and vertebral arteries.

The ScienceDirect, PubMed, MEDLINE, NCBI and SAGE database were searched in April 2014 for publications containing information about “to-and-fro” sign in the diagnosis of pseudoaneurysms in various arterial vessels in the title of the report. Abstracts resulting from this search were reviewed for relevance to the clinical outcomes from the procedure. Full manuscripts were retrieved and reviewed if they contained information regarding the evaluation of the evidence on the role of “to-and-fro” sign in the diagnosis of pseudoaneurysms and the published clinical literature in this field.

Only those papers published between 2000 and 2013 were included in the outcomes analysis, and this was due to the tremendous development in this medical diagnostic specialty at the beginning of the new millennium so far. Regarding place of the study or journal type in order to include all available sources of experience.

GENERAL SONOGRAPHIC FEATURES REGARDING ARTERIAL PSEUDOANEURYSMS

US is a readily available imaging modality, which does not expose the patient to ionizing radiation. Grayscale and color Doppler techniques are utilized, and standardized protocols in an accredited ultrasound

laboratory will increase the likelihood of detection of pseudoaneurysm. Grayscale is often initially performed. Linear (high frequency) US probe has acceptable depth penetration and visualization should be used. After a general overview of the area of concern, attention should be given to any anechoic collections or regions of hematoma^[19].

Color Doppler is placed in any anechoic collection to detect flow. The flow can be characterized if the scale is properly set to avoid aliasing due to under sampling. Spectral Doppler is then performed if flow is detected to help characterize arterial vs venous flow. Spectral waveforms may be diagnostic of the pseudoaneurysm and help to exclude arteriovenous fistula (AVF). A low wall filter may be initially used to detect slow flow, and the waveform should fill at least two-thirds of the spectral window. In grayscale, a patent pseudoaneurysm appears as an anechoic rounded or ovoid structure. Because other fluid collections, including cysts, seromas, or hematomas can have this appearance, color Doppler imaging is used to confirm the presence of blood flow within the pseudoaneurysm. When present, thrombus in the pseudoaneurysm appears mildly echogenic or hypoechoic without flow; it may be mural or centrally fill a portion of the pseudoaneurysm lumen^[1]. Turbulent blood flow is illustrated by interchangeable coloring appearance, either in red or blue color. If large areas of color aliasing are identified in the adjacent tissues, grayscale may help to differentiate pseudoaneurysm from tissue reverberation associated with AVF^[19].

The scientific foundation of "to-and-fro" waveform at DDU and its clinical use in the diagnosis of pseudoaneurysms in various arterial vessels, could be discussed on the basis that, the DDU monitoring will present the conventional "to-and-fro" waveform with blood flow of the bidirectional pattern at the neck of pseudoaneurysm. Occasionally, the neck is the only patent portion of the pseudoaneurysm if partial thrombosis has occurred^[19].

INCIDENCE OF PSEUDOANEURYSM IN THE PERIPHERAL ARTERIES, ABDOMINAL AORTA AND NECK ARTERIES

The incidence of pseudoaneurysms has increased in hospital based practice, due to the large number of invasive procedures performed^[20]. Their incidence varies in the literature due to different definitions, methods of interrogation and presence of certain complications^[21]. According to medical literature, the incidence of pseudoaneurysms ranges from 0.1% to 6% and up to 0.5% to 9%, depending on the diagnostic or therapeutic procedure performed^[22,23].

The frequency of peripheral arteries pseudoaneurysms is much less in the upper extremities than in the lower extremities (less than 2% of all lesions)^[24,25].

Aortic pseudoaneurysms are rare, life-threatening sequelae of cardiac surgery^[26]. The incidence, risk factors, and natural history of aortic pseudoaneurysm are unknown, because so few cases have been reported^[27]. Pseudoaneurysms of the abdominal aorta are rare, especially those found to be mycotic. Abdominal aorta pseudoaneurysms following trauma have been reported fairly often^[28]. Common carotid artery pseudoaneurysms are rare and potentially lethal, and adequate treatment is warranted in order to prevent rupture or neurologic sequelae^[29]. Vertebral arteries pseudoaneurysm formation after central line placement has been well documented in the literature, with an incidence rate of 0.05% to 2%^[30,31].

AETIOLOGY OF PSEUDOANEURYSM IN THE PERIPHERAL ARTERIES, ABDOMINAL AORTA AND NECK ARTERIES

Iatrogenic complication

Unintentional pseudoaneurysm due to surgical intervention for numerous medical procedure (e.g., pseudoaneurysm can be induced in femoral artery during cardiac catheterization). It accounts up to 70%-80% of the incidence of pseudoaneurysms^[32].

Trauma

It had been estimated that 79% of pseudoaneurysms are traumatic in origin of the internal solid organs such as liver, kidneys, pancreas, and gastrointestinal tract of the digestive system^[33].

Injury by tumor

Pseudoaneurysm can be initiated due to blood vessel erosion by an erosive tumor, either benign or malignant. This is most commonly seen in osteochondroma, neurofibromatosis, leukemia, and lymphoma^[34]. Yang *et al*^[35] reported that 25% of pseudoaneurysms are caused by neoplastic aneurysms as choriocarcinoma. Kim *et al*^[36] also reported leukemia and lymphoma as a cause of pseudoaneurysm by damaging the arterial vessel wall.

Infection

Pseudoaneurysm can be initiated by primary (wall infection) or secondary (adjacent focus) infection of blood vessels. It has been reported that pseudoaneurysms are more frequent in incidence than true aneurysms, this is because the infection can disturb blood vessels wall more easily^[37].

Vasculitis and inflammation

Formation of pseudoaneurysm in blood vessels is caused by destroying the elastic fibers of the media, induced by inflammation. The majority of pseudoaneurysms is caused by Behcet's syndrome, while pseudoaneurysms caused by primary vasculitis are not common in incidence^[38].

Atherosclerosis

Aortic pseudoaneurysms are caused by atherosclerotic ulcer due to disturbance of internal elastic lamina, which can lead to aortic rupture or aortic dissection^[39].

Infarction

Another cause of pseudoaneurysm is infarction of the left ventricle. It occurs due to separation of the left ventricle free wall enclosed by superimposing adherent pericardium, generated what has been named "pseudoaneurysm of the left ventricle"^[40].

MANAGEMENT OF PSEUDOANEURYSM IN THE PERIPHERAL ARTERIES, ABDOMINAL AORTA AND NECK ARTERIES

Surgical approach

The gold standard of pseudoaneurysm treatment in general is surgical intervention. The intervention includes arterial ligation, organectomy either partially or totally, and resection using bypass techniques. Surgical treatment is associated with increased morbidity and mortality as compared with minimally invasive treatment options. The complications associated with surgery include bleeding, infection, lymphocele formation, radiculopathy, perioperative myocardial infarction, and death^[41].

Endovascular approaches

Endovascular approaches to therapy offers distinct advantage to conventional surgical repair in patients with visceral pseudoaneurysms^[42]. Several endovascular techniques have been described to treat pseudoaneurysms. These techniques include catheter-guided embolization with use of coils or detachable balloons^[43,44]. Similar management principles are applied to management of aortic pseudoaneurysms^[45]. Compared to other techniques, endovascular procedures have lower morbidity and mortality rate in the management of pseudoaneurysm compared to surgical intervention^[19].

Percutaneous approach

Percutaneous US-guided thrombin injection is an important treatment option for the treatment of pseudoaneurysms. This approach appears to be a safe and expeditious method for treating postcatheterization femoral pseudoaneurysms. It has significant advantages with respect to ultrasound guided compression repair or surgical repair^[19]. Recently, the percutaneous thrombin injection was introduced for the treatment of iatrogenic pseudoaneurysm of femoral artery^[46,47].

In addition to that, this procedure can be used to treat arteries above the inguinal ligament and is considered as an alternative technique to US-guided compression in order to avoid arterial rupture^[48]. Complications of thrombin injection are uncommon, occurring in 0%-4%

of cases^[12]. Most reported complications involve the escape of thrombin into the native circulation, causing distal embolization. This occurs in as many as 2% of all patients treated^[41].

US-guided compression

US-guided compression of pseudoaneurysms is a safe and cost-effective method for achieving pseudoaneurysm thrombosis. However, it has been demonstrated that the success rate is higher and procedure time is much shorter for thrombin injection compared with US compression^[48]. Furthermore, compression of pseudoaneurysm is painful to the patient and time-consuming for the practitioner. US-guided compression is more likely to fail in a patient with anticoagulation, large pseudoaneurysm size, chronic pseudoaneurysm, and longer procedure time. The incidence of complications is small but they occasionally do occur^[19].

TO-AND-FRO WAVEFORM IN PSEUDOANEURYSMS OF UPPER EXTREMITY ARTERIAL VESSELS

The characteristic appearance of pseudoaneurysm in upper extremities arterial vessels is the extraluminal pattern of blood flow, which shows variable echogenicity, interval complexity, and "to-and-fro" flow pattern on color Doppler ultrasonography (CDUS)^[49,50]. It has been estimated that 2% to 3% of pseudoaneurysm in Subclavian artery occur due to blunt trauma, or injuries after clavicle fracture^[51].

Pseudoaneurysm of radial artery could be caused also as a result of bacterial infection at cannulation site^[8]. It has been considered that radial artery pseudoaneurysm is a rare pathological condition accounting and incidence of 0.048%^[52].

Rozen *et al*^[53] reported that pseudoaneurysm of radial artery are a common finding in patients with anticoagulated or patient under antiplatelet treatment. It's crucial to deliberate pseudoaneurysm diagnosis in any swelling that may presents swelling in order to avoid puncture or incision of the vessel because this swelling could be tender and warm^[54].

Several imaging modalities may be used to detect pseudoaneurysms in upper extremity arterial vessels, including conventional arteriography, computed tomography (CT) angiography, radionuclide angiography, and CDUS. US imaging is a diagnostic method of choice required to access pseudoaneurysm before US guided intervention is established for pseudoaneurysm of radial artery^[55,56]. CDUS is accurate, noninvasive imaging technique, and widely available. Therefore, it can be used to diagnose pseudoaneurysm of radial artery without even a side effect^[51,57,58]. US imaging procedure has the ability to differentiate between solid and cystic lesions adjacent to the radial artery in the wrist area^[53]. The sonographic appearance of the

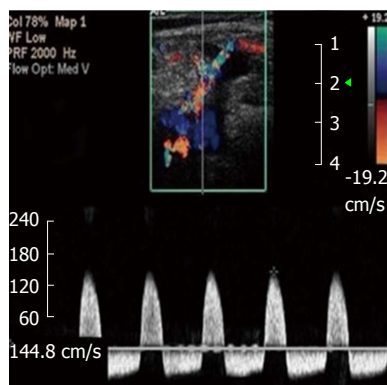


Figure 1 To-and-fro spectral waveform of a pseudoaneurysm; neck wasn't depicted^[65].

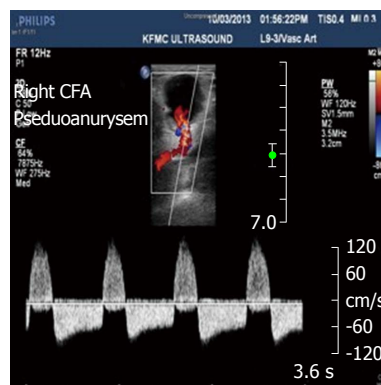


Figure 2 Right common femoral artery pseudoaneurysms associated with the characteristic findings of a pulsatile mass, a palpable thrill, and an audible "to-and-fro" murmur. CFA: Common femoral artery.

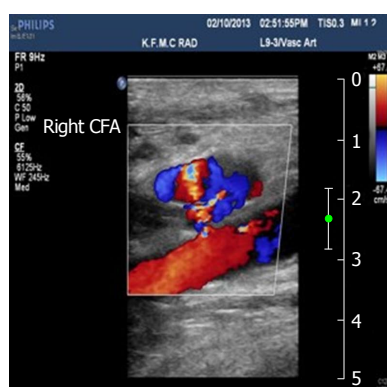


Figure 3 Pseudoaneurysm communicated with the right common femoral artery, and the blood flow patterns and velocities in the affected area. CFA: Common femoral artery.

radial artery characterized by a feature of sonolucent pulsatile tube^[59]. Spectral Doppler of the radial artery pseudoaneurysm is usually shown both "yin-yang" sign and "to-and-fro" waveform^[51,57,60].

A recent report describes the attempted repair of a brachial artery pseudoaneurysm in an infant that resulted in the thrombosis of the underlying brachial artery and an emergent thrombectomy^[61]. The light of the fact that neonates brachial artery injuries are uncommon, but induced by a brachial artery puncture. Therefore, this intervention is not recommended in neonates^[62]. In the literature induction of brachial artery pseudoaneurysm due to venipuncture was documented in two instances^[63]. Arterial injuries can be diagnosed promptly by using Duplex US imaging technique (Figure 1), without any further need for angiography^[64,65]. Also DDU can be up to 95% to 100% sensitive for diagnosing vascular injuries in the hands of highly qualified personnel with a high index of suspicion^[5].

TO-AND-FRO WAVEFORM IN PSEUDOANEURYSMS OF LOWER EXTREMITY ARTERIAL VESSELS

The incidence of pseudoaneurysm in lower extremity

arterial vessels was estimated to be ranged from 3.5%-5.5% and 0.1%-0.2% of the Interventional examination and diagnostic radiography, in that order^[66,67]. Femoral artery pseudoaneurysms are usually accompanied with a certain features of an audible "to-and-fro" pulsatile mass and touchable thrill (Figure 2). Duplex US of femoral artery (Figure 3) is the diagnostic method of choice for the diagnosis of Pseudoaneurysm^[67]. This imaging technique can reveal the blood flow waveform, blood clotting, and the relation with the femoral artery^[67].

The common femoral artery is the most frequent site of pseudoaneurysm in the lower extremities (Figure 4). This can be attributed to the localization of the common femoral artery inside the neurovascular sheath and it's supported by the head of the femur. Also the common femoral artery site is the place of choice to introduce cardiac catheterization. The incidence of pseudoaneurysm in the superficial femoral artery is less frequent in occurrence when compare with the common femoral artery because this artery is usually not selected for cardiac catheterization as a result of insufficient supportive tissue around it^[68,69].

Also popliteal artery is the most frequent region for pseudoaneurysm incidence because this artery is not supported by muscular tissue to shield it from dilatation and bending, compared to superficial and deep femoral arteries^[70]. Enlarging and pulsatile mass located in the popliteal artery are the common features of aneurysmal lesion^[70,71]. There are a similarity in diagnostic findings between popliteal artery mycotic pseudoaneurysm and other pseudoaneurysms on the basis of CDUS finding^[2,72].

Pseudoaneurysms of the anterior tibial artery and tibioperoneal trunk are exceedingly rare^[73,74]. Owen *et al*^[75] reported that pseudoaneurysms of the tibial arteries can be treated using percutaneous injection of thrombin and tissue adhesive. To prevent sudden incidence of a thrombosis in the native vessel, occlusion balloon can be used. An important study reported by Davis *et al*^[76] showed that pseudoaneurysm can be treated with percutaneous injection of thrombin at the posterior tibial and distal superficial femoral arteries. Pseudoaneurysm

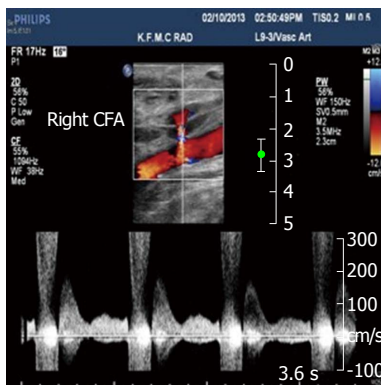


Figure 4 Spectral analysis of the right common femoral artery showing prominent flow with a component of reversed flow, in the region of the neck of the pseudoaneurysm. CFA: Common femoral artery.

can be formed during surgical replacement of the knee joint. This can occur either direct (intra-operative) or indirect (intimal plaque disruption)^[77].

Some studies reported that the incidence of pseudoaneurysms or aneurysms are rare in the dorsalis pedis artery and usually accompanied with trauma^[78-80]. Surgical intervention is preferred to reduce the risk of complication, such as ischemia, arterial rupture, and thrombosis^[80,81].

To differentiate between a hematoma and pseudoaneurysm in lower extremities arterial vessels, DDU can be used to establish the accurate diagnosis by demonstrating the relation between the injured artery and aneurysmal neck^[82]. In addition, triplex Doppler US can be used for diagnosis of pseudoaneurysm, by presenting “yin-yang” pattern. Bearing in mind that this pattern don’t usually differentiate between pseudoaneurysm and pulsating hematoma^[83].

TO-AND-FRO WAVEFORM IN PSEUDOANEURYSMS OF ABDOMINAL AORTA

The incidence of abdominal aneurysms has been established by Ertürk *et al*^[84] to be 1% of the overall abdominal aneurysms, concluding that pseudoaneurysms of abdominal aorta has a very low incidence. Pseudoaneurysms of the abdominal aorta are often diagnosed late or after catastrophic complications^[85]. Pseudoaneurysms of abdominal aorta caused by medical interventions, these interventions are abdominal surgery, Interventional guided by X-ray imaging of the abdomen, as a complication of abdominal aortic aneurysm, vasculitis, external abdominal trauma, and mycotic aneurysms. Pseudoaneurysms due to external abdominal trauma showed a high incidence in patients treated with anticoagulant or antiplatelet^[86].

Shanley *et al*^[87] reported that pseudoaneurysms could be developed in the majority of the visceral artery. A different incidence rate was noted in the splenic artery (46%), renal artery (22%), hepatic artery (16.2%),

and pancreaticoduodenal artery (1.3%)^[88-90]. Those involving the gastroduodenal artery constitute just 1.5% of all published visceral artery aneurysms^[90].

Pseudoaneurysms also took place as a result of a combination of an artery impeded with the wall of pseudocysts^[91]. Gastroduodenal and splenic artery pseudoaneurysms are silent in the majority of cases, but in some cases, patients may experience upper abdominal pain or anemia due to bleeding in the gastrointestinal tract or peritoneal cavity^[92].

Pseudoaneurysms of splenic artery in different patients are caused by pancreatitis, either chronic or acute pancreatitis. The majority of these patients is characterized by a history of excessive alcohol consumption. The main cause of pseudoaneurysms formation by the aforementioned method is due to the digestion of splenic artery by pancreatic enzymes^[93]. Pseudoaneurysm development in the splenic artery due to blunt abdominal trauma had been reported by Sugg *et al*^[94]. Splenic artery slow blood flow is a predisposing factor of pseudoaneurysm as reported by Norotsky *et al*^[95]. In recent year’s noninvasive procedure, therefore the incidence of pseudoaneurysm of splenic artery is increasing in incidence among patients^[96]. It has been reported that pseudoaneurysm may develop rarely due to peptic ulcer or as a result of iatrogenic causes. An a tiny number of patients developed pseudoaneurysm in the splenic artery without specific reasons^[10].

False aneurysms of the gastroduodenal artery can arise from an impairment in the integrity of the arterial wall, by direct injury *via* a biopsy needle, enzymatic digestion, as a result of pancreatitis, surgery, or trauma^[97]. This defect can lead to the formation of an open communication between the lumen of the artery and its surroundings, which can have two fates. If no soft tissues surround the site of injury, hemorrhage into the peritoneal cavity can occur. The presence of surrounding soft tissue, conversely, can result in containment of the hematoma, which can be followed by fibrosis and enlargement^[98]. Pseudoaneurysms have been reported to spontaneous thrombosis, but this is a rare event occurring only under certain conditions^[99]. More often, the hematomas become unstable and rupture, being associated with a mortality rate of around 50%^[100].

Diagnosis of gastroduodenal and splenic pseudoaneurysm can be made with a number of imaging methods. Contrast-enhanced CT and Doppler sonography are widely used as noninvasive techniques in the diagnosis and monitoring of the lesion^[101,102]. On contrast-enhanced CT, a pseudoaneurysm appears as an eccentric mass with a well-defined region of central enhancement in the arterial phase. Doppler sonography shows a mass that generally has a well-defined, solid peripheral component composed of a thrombus and a central anechoic area of varying size. This cavity fills on color Doppler imaging and produces the typical “yin-yang” pattern of pseudoaneurysms anywhere in the body. A “to-and-fro” pattern at the neck of the lesion is confirmatory of a pseudoaneurysm.

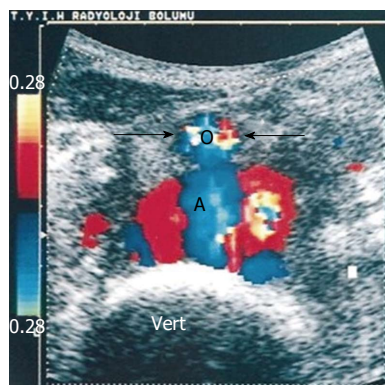


Figure 5 Transverse color Doppler sonogram shows turbulent flow in the pseudoaneurysm. Note the anterior displacement of the normal-sized aorta (arrows and AO) and the drape of the posterior wall of the pseudoaneurysm over the anterior aspect of the spine (vert)^[84].



Figure 6 Color Doppler sonogram showing the blood flow of the right common carotid artery, and the haematoma with the rotatory flow within its cavity (arrows). Note the large neck connecting the carotid to the pseudoaneurysm^[90].

Angiography remains the definitive modality used to diagnose, locate, and evaluate the presence of a gastroduodenal and splenic pseudoaneurysm^[101,102]. The advantage of this method is that it can be used in the treatment of the lesion as well. Angiography is useful in establishing confirmation of the diagnosis and in cases of an acute rupture or major gastrointestinal bleeding requiring immediate care^[93]. The sonographic appearance of abdominal aortic pseudoaneurysm is anechoic blood accumulation in a sac nearby within the artery. This accumulation can be detected by using color Doppler^[84]. Sonographic examination of patient using color duplex Doppler revealed a pattern of turbulent flow within pseudoaneurysm illustrated in (Figure 5). Whirlwind flow and "to-and-fro" waveform are seen in the neck of pseudoaneurysm also by using pulsed Doppler^[103].

The limitations of color duplex Doppler in the diagnosis of pseudoaneurysms are obese patients and the presence of excessive gasses in the bowel. Nevertheless ultrasound should be used to establish preliminary diagnosis, especially for patient with pulsatile abdominal masses^[84,104].

TO-AND-FRO WAVEFORM IN PSEUDOANEURYSMS OF CAROTID AND VERTEBRAL ARTERIES

Carotid and vertebral artery pseudoaneurysms are uncommon lesions that may occur as sequelae of blunt trauma, cancer or radiation necrosis, and mycotic infection^[104]. Although Doppler ultrasound is a noninvasive imaging procedure, more accurate imaging modalities have been developed such as magnetic resonance angiogram or angiography. However US is the imaging method of choice (Figure 6) to study the midcervical portion of the carotid or vertebral arteries^[105-107].

The degree of confidence is high in detection carotid (mid cervical region) and vertebral artery pseudoaneurysms. While the degree of confidence is low in the detection of an intrathoracic segment of the carotid and vertebral arteries^[108].

Duplex ultrasound is used on a routine basis to evaluate atherosclerotic lesions. The main findings include dissection, occlusion, pseudoaneurysms, and intimal flaps. Nemours studies used DDU reported that around 92%-100% sensitivity in detection of arterial lesions due to neck trauma^[109-111]. The contour of pseudoaneurysms affecting carotid arteries showed variable color flow, depending on the presence of thrombosis^[112], while swirling blood flow and "to-and-fro" pattern is shown by spectral Doppler^[113]. In common carotid arteries, ultrasound is an effective means of diagnosing a pseudoaneurysm. It may also be used for serial follow the progression of these occurrences once they are diagnosed, as well as to aid in treatment in certain cases^[114]. When investigated internal carotid artery pseudoaneurysm by color Doppler it shows swirling of blood flow within the pseudoaneurysm with a communicating channel of the parent artery (yin-yang phenomenon), while pulse Doppler shows "to-and-fro" waveforms^[115].

Vertebral artery pseudoaneurysms typically present over the course of several days as a pulsatile mass. Duplex US is used to define the size of the pseudoaneurysms. Adequate visualization of the pseudoaneurysms neck of lesions arising vertebral arteries is limited owing to the overlying clavicle. Angiography is often indicated in order to precisely define the site of injury^[30]. However, US examination of vertebral artery pseudoaneurysms is necessary in uncertain or difficult case from the beginning because it is convenient and sensitive in follow-up evaluation^[116].

CONCLUSION

In conclusion, this review study showed that gray scale and Doppler ultrasound play an essential role in the diagnosis of pseudoaneurysms. The use of spectral Doppler in the diagnosis of pseudoaneurysms depends upon the presence of "to-and-fro" waveform. Incidence

of arterial pseudoaneurysms are varied in the different body vasculature. Also the choice of pseudoaneurysms treatment is size dependent.

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