Origin of a common trunk for the inferior phrenic arteries from the right renal artery: a new anatomic vascular variant with clinical implications

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Abstract

The inferior phrenic arteries constitute a pair of important vessels, supplying multiple organs including the diaphragm, adrenal glands, esophagus, stomach, liver, inferior vena cava, and retroperitoneum. The vast majority (80–90%) of inferior phrenic arteries originate as separate vessels with near equal frequency from either the abdominal aorta or the celiac trunk. Infrequently, the right and left inferior phrenic arteries can arise in the form of a common trunk from the aorta or from the celiac trunk. We herein present three patients with a new anatomic vascular variant: a common trunk of the inferior phrenic arteries arising from the right renal artery. In one case, the left inferior phrenic branch of the common trunk provided collaterals connecting with a supra-diaphragmatic branch of the left internal mammary artery and in another with the lateral wall of the pericardium. Angiographic identification of a common trunk for the inferior phrenic arteries arising from the right renal artery is important for proper diagnosis and clinical management. The presence of this unique vascular variant can impact revascularization of the renal arteries.

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1. Introduction

The inferior phrenic arteries constitute a pair of important vessels, supplying multiple organs including the diaphragm, adrenal glands, esophagus, stomach, liver, inferior vena cava, and retroperitoneum [1–7]. The vast majority (80–90%) of inferior phrenic arteries originate as separate vessels with near equal frequency from either the abdominal aorta or the celiac trunk [3,7,8]. Infrequently, the right and left inferior phrenic arteries can arise in the form of a common trunk from the aorta or from the celiac trunk [1,2,8]. Angiographic identification of these vessels and their variants is important for proper diagnosis and clinical management.

We herein present three patients in whom selective renal arteriography identified a new anatomic vascular variant: a common trunk of the inferior phrenic arteries arising from the right renal artery. In one case, the left inferior phrenic branch of the common trunk provided collaterals connecting with a supradiaphragmatic branch of the left internal mammary artery and in another with the lateral wall of the pericardium.

2. Case 1

A 60-year-old Caucasian male with coronary artery disease, diabetes mellitus Type 2, hypertension, and hyperlipidemia underwent a three-vessel coronary bypass...
surgery in 2004. A year later, he developed angina pectoris and underwent a percutaneous coronary intervention with placement of three stents in the proximal and middle segments of the circumflex artery. In 2008, recurring angina led to angiography which demonstrated total occlusion of the stents; however, attempted targeted percutaneous coronary intervention failed. In 2009, he presented again with unstable angina pectoris. Cardiac catheterization demonstrated a patent left main coronary artery and 100% occlusion of the proximal left anterior descending artery and the proximal left circumflex artery. The right coronary artery was a dominant, patent vessel supplying a posterior descending artery. The left internal mammary artery graft to the left anterior descending artery was patent with adequate distal flow into the native vessel. Saphenous vein grafts to an obtuse marginal branch of the circumflex artery and the posterior descending artery were completely occluded at their aortic origin. Selective renal angiography demonstrated normally arising and patent bilateral renal arteries. A large common trunk of the phrenic arteries measuring 4 mm in diameter.

Fig. 1. (A) Selective angiogram demonstrating the origin of the common trunk of the inferior phrenic arteries (IPA) from the proximal right renal artery (Rt. RA). The bifurcation of the common trunk IPA into right (RIPA) and left (LIPA) inferior phrenic arteries is depicted. (B) The middle segments of the RIPA and LIPA. (C) Distal segment of the LIPA providing trans-diaphragmatic (TD) collateral. Occluded stents are shown in the circumflex (Cx) artery.
(Fig. 1A) originated from the proximal portion of the right renal artery (diameter 5.5 mm). The common trunk ascended vertically for 26-mm branching into left and right phrenic arteries (Fig. 1B). The proximal segment of the left inferior phrenic artery measured 3.5 mm in diameter and its distal segment measured 2.5 mm. This segment supplied collateral branch (1.7-mm diameter) that crossed the diaphragm connecting with a left superior phrenic artery branch of the left internal mammary artery (Fig. 1C). The proximal segment of the right inferior phrenic artery measured 2.8 mm and its distal segment 1.7 mm, terminating normally below the right diaphragm.

3. Case 2

An 87-year-old Caucasian male presented with angina pectoris. He had a history of hypertension and tobacco abuse. Myocardial perfusion stress test demonstrated inferior and anterior ischemic perfusion defects. Coronary arteriography revealed a patent left main coronary artery. The proximal segment of the left anterior descending artery contained a 99% thrombotic lesion and the circumflex artery was patent. The middle portion of the right coronary artery exhibited a 95% eccentric atherosclerotic lesion. The patient underwent a successful two-vessel percutaneous coronary intervention. Selective renal arteriography demonstrated a 20% ostial stenosis of the left renal artery without an aortic-renalling pressure gradient. A patent right renal artery (diameter of 6.5 mm) gave rise to a common trunk of the inferior phrenic artery 51 mm in length and 2.5 mm in diameter (Fig. 2A). The vessel then ascended and branched into right and left inferior phrenic arteries. The proximal segment of these vessels measured 1.5 and 1.9 mm, respectively. A hepatic branch arose from the proximal segment of the left inferior phrenic artery (Fig. 2B). The diameter of the distal segments of the right inferior phrenic artery and left inferior phrenic artery reached their corresponding sub-diaphragmatic locations measuring 1.2 and 1.6 mm, respectively.

4. Case 3

A 50-year-old African-American patient was admitted with unstable angina pectoris. He sustained a myocardial infarction 3 years earlier complicated by left ventricular thrombus and resultant cerebrovascular embolization with residual neurologic deficit. The patient also had hypertension, diabetes mellitus, and dyslipidemia. Cardiac catheterization demonstrated single vessel atherosclerotic disease with a long, eccentric plaque causing 99% stenosis of the ostial–proximal segment of left anterior descending coronary artery. This lesion contained a heavy thrombus burden. Thrombus was also present in the middle and distal portions of this vessel resulting in poor antegrade flow. The patient underwent a successful percutaneous revascularization of the left anterior descending coronary artery using excimer laser, rheolytic thrombectomy, and stenting. The target lesion was decreased to 0% residual narrowing and normal antegrade flow was restored along the left anterior descending coronary artery.

Right renal angiography revealed a common trunk for the inferior phrenic arteries originating from the proximal renal artery measuring 3.1 mm in diameter (Fig. 3A). It
ascended vertically for 13 mm then bifurcated into right (Fig. 3B) and left inferior phrenic arteries. These vessels measured 2.4 and 2.75 mm, respectively, at their proximal segment. The middle portion of these phrenic arteries was connected by several delicate collaterals traversing across the mid abdomen. Distally, these arteries measured 1.2 and 1.6 mm, respectively (Fig. 3C). The superior branch of the left inferior phrenic artery provided delicate transdiaphragmatic collaterals (Fig. 3D) reaching the lateral portion of the pericardium.

5. Methods

The clinical data and angiograms of the three patients were reviewed by experienced cardiologists and a radiologist who
reached a consensus regarding the origin and distribution of the inferior phrenic artery’s common trunk, its branches, and the extent of coronary artery disease. For the purpose of quantitative angiographic measurement, a Philips (Philips Medical Systems, Netherlands) Allura Xper FD 20 radiologic software system was used. Extensive review of anatomy, embryology, pathology, vascular medicine, radiology, and interventional cardiology textbooks was conducted for descriptions of inferior phrenic arteries and their variants. Using PubMed /Medline Search, the keywords “replaced, anomalous, aberrant, ectopic and variant” were paired with “inferior phrenic artery” and “common trunk inferior phrenic artery” for identification of previous publications.

6. Discussion

This article documents several unique features of vascular anatomy and angiography: (1) presentation of a new vascular variant consisting of a common trunk of the inferior phrenic arteries arising from the right renal artery, (2) measurements of the dimensions of the common trunk and its main branches, (3) identification of distinct trans-diaphragmatic collaterals.

6.1. Anatomy of the inferior phrenic artery

The inferior phrenic arteries develop in the meshwork of ventrolateral vessels supplying the mesonephros of the embryo [1–7]. A small percent arise from the right renal artery, proper [2] or left hepatic artery [9,10], left gastric artery [11], superior mesenteric artery [1–3], left renal artery [3], contralateral inferior phrenic artery [12], and exceedingly rarely from a spermatic artery [13] or aberrant suprarenal artery [14]. As the left and right inferior phrenic arteries traverse upward, they give rise to the left and right superior adrenal arteries, respectively. Behind the inferior vena cava on the right and the esophagus on the left, the inferior phrenic arteries branch into their respective anterior and posterior divisions. Their distal segments supply muscular branches to the diaphragmatic crura and accessory spleen, when present [15]. These arteries are a major source of blood flow to hepatocellular and gastric carcinomas and to renal, esophageal, or pulmonary tumors. Surgery or trauma to the inferior phrenic arteries can cause hemoperitoneum, hemoptysis, or gastroesophageal, diaphragmatic, or hepatic bleeding [2,3,15]. In the settings of severe occlusive vascular disease these vessels constitute an important source of collateral flow to the intestinal circulation [4] and can provide crucial renal perfusion [1].

6.2. Variants of inferior phrenic arteries arising from the renal arteries

In cases of variant origin of the inferior phrenic artery from renal arteries, multiple other variations of the paired arteries of the abdominal aorta may exist [16,17]. The most frequent variant is the origin of a right inferior phrenic artery from the right renal artery. In a study of 300 cadavers by Loukas et al. [18], the right inferior phrenic arose from the right renal artery in 17% of cases. Separate origin of the right and left inferior phrenic arteries from the right renal artery were identified in 4%. Specifically, the authors noted that in cases of either right or left inferior phrenic artery emergence from the right renal artery, they were anatomically independent and did not have a common stem. Our three patients present a newly described vascular variant consisting of a common trunk of the inferior phrenic arteries arising from the right renal artery. To the best of our knowledge, no previous reports of this particular variant have been published. Interestingly, in a comprehensive autopsy study of 200 cadavers by Pick and Anson in [7] 1940, the inferior phrenic artery arose from a renal artery in 5.8% of cases, with the authors emphasizing that “in no instance do the right and left inferior phrenic arteries arise by a common trunk from one of the renal vessels.” In another series of 425 autopsies, Creig et al. [13] did not find even a single case of a common trunk inferior phrenic artery originating from a renal artery. The American edition [19] as well as the British edition [20] of Gray’s anatomy gives comprehensive account of inferior phrenic arteries and their variants but does not mention an origin of a common trunk from the renal arteries.

The size of either normal or variant inferior phrenic arteries is seldom mentioned in the literature. Kahn [1] reported, based on angiographic measurements, a 2.2-mm internal diameter for the right inferior phrenic artery (range 1.4–3.2 mm) and 2 mm (range 1.4–2.8 mm) for the left inferior phrenic artery. The relatively large size of the common trunk and its main branches, especially the left inferior phrenic artery as identified in our patients, could represent a physiologic–morphologic adaptation to an increased demand for flow. Such physiologic adaptation had been demonstrated by a recent computed tomographic (CT) study which showed asymmetric enlargement of the right inferior phrenic artery when supplying collaterals to hepatocellular carcinomas [21] or to the liver in cirrhosis [22].

6.3. The inferior phrenic arteries as a source of collaterals

In case of severe abdominal vascular occlusions, the inferior phrenic arteries can serve as an important source of collateral blood supply toward occluded vessels. For example, anastomoses with superior phrenic arteries have been described [1,3,7,18]. In two of our cases, newly described transdiaphragmatic collaterals toward the coronary vasculature have been identified. Interestingly, in one of the patients the transdiaphragmatic collaterals connected with a supra diaphragmatic branch of the left internal mammary artery while in another they reached the lateral region of the pericardium. The latter is suggestive of collateral development due to under perfusion of myocardial territory by the
occluded left anterior descending coronary artery. Altogether, we speculate that the presence of these unique collaterals across the diaphragm related to the critical degree of underlying coronary atherosclerotic disease.

6.4. Clinical implications

Identification of anatomic vascular variants is required for accurate diagnosis and clinical management of patients with coronary and peripheral vascular disease [23,24]. The advance of noninvasive imaging modalities such as CT and magnetic resonance angiography is expected to increase the number of diagnostic renal and vascular studies [25]. Clinicians from several disciplines should expect to encounter this unique vascular variant. Renal arteries containing ostial or proximal stenosis with an adjacent common trunk for the inferior phrenic arteries will present a challenge for percutaneous revascularization and other interventions.

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