International Journal of Research in Medical Sciences
*Thamke S et al. Int J Res Med Sci. 2015 Jan;3(1):282-286*
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: 10.5455/2320-6012.ijrms20150151

**Research Article**

# Normal and variant origin and branching pattern of inferior phrenic arteries and their clinical implications: a cadaveric study

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**Received:** 6 December 2014
**Accepted:** 18 December 2014

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## ABSTRACT

**Background:** Inferior phrenic arteries, which constitute the chief arterial supply to the diaphragm, are generally the branches of abdominal aorta, however, variations in their mode of origin is not uncommon. Very less information is available regarding the functional anatomy of the inferior phrenic artery in anatomy textbooks.
**Methods:** The present study was conducted utilizing 36 formaline-fixed cadavers between 22 years to 80 years over a period of 5 years. The frequency and anatomical pattern of the origin of the right and left inferior phrenic arteries were studied.
**Results:** On the right side, the inferior phrenic artery arose independently from abdominal aorta in 94.4% cases and on the left side in 97.2% cases.Other sources of origin were seen in 5.55% cases. Left hepatic artery was seen as the source of origin for right inferior phrenic artery in one case while in second case left gastric artery was the source for both the right and left inferior phrenic artery. The right inferior phrenic artery is the most common source of collateral arterial supply to hepatocellular carcinoma, next to the hepatic artery.
**Conclusion:** Knowledge of variations of inferior phrenic artery origin could be valuable during treatment of hepatic neoplasm, liver transplants, biliary tract surgery and during tanscatheter oily chemoembolisation technique.

**Keywords:** Inferior phrenic artery, Hepatocellular carcinoma, Abdominal Aorta, Coeliac trunk, Embolization, Diaphragm

## INTRODUCTION

Inferior phrenic arteries are two small lateral aortic branches, which supply the diaphragm, but present much diversity in their origin alongwith presence of supplementary phrenic vessels.[1] They may arise separately from the front of the aorta, immediately above the celiac artery or by a common trunk, which may spring either from the aorta or from the celiac artery. Sometimes one is derived from the aorta and the other from one of the renal arteries; they rarely arise as separate vessels from the aorta. They diverge from one another across the crura of the diaphragm and then run obliquely upward and laterally upon it's under surface. The left phrenic artery passes behind the oesophagus and runs forward on the left side of the oesophageal hiatus. The right phrenic artery passes behind the inferior vena cava and along the right side of the foramen in the diaphragm which transmits that vein. Near the posterior part of the central tendon, each vessel divides into a medial and a lateral branch. The medial branch curves forward, and anastomoses with its fellow of the opposite side and with the musculophrenic and pericardiacophrenic arteries. The lateral branch passes toward the side of the thorax and anastomoses with the lower intercostal and musculophrenic arteries. The lateral branch of the right

phrenic gives off a few vessels to the inferior vena cava and the left one, some branches to the oesophagus. Each vessel gives off superior suprarenal branches to the suprarenal gland of its own side. Few twigs are also given off to the spleen, liver and retroperitoneum.[2]

Apart from the usual origin, other sources of origin may be renal, supra renal, hepatic, left gastric or superior mesenteric arteries in 8% of the cases.[3] Information regarding the functional anatomy of the right inferior phrenic artery and left inferior phrenic artery is very brief and lacking in detail in anatomy text- books. In the past few years, articles have been published and stressed upon the fact that right inferior phrenic artery is the most common extrahepatic feeding artery supplying the hepatocellular carcinoma. The great importance of such knowledge lies in the fact that an unresectable hepatocellular carcinoma can be treated by transcatheter embolization of not only its typical blood supply, the right or left hepatic arteries, but also by embolization of a right inferior phrenic artery, if involved.[4]

The inferior phrenic artery is not only important in the treatment of hepatocellular carcinoma but it is also reported that gastric haemorrhage can occur due to bleeding from the left inferior phrenic artery after treatment of the left gastric artery with embolization.[5] The inferior phrenic arteries also contribute to arterial supply of adrenal glands and are therefore of great importance in angiographic examination for adrenal lesions.[6] Few publications are available in relation to the role and detailed anatomy of the with inferior phrenic artery respect to their involvement in hepatocellular carcinoma[7] and similarly, few have been produced with direct focus on the elucidation of the origin and distribution of these arteries.[8] The study of common variations in origin of these vessels and their respective frequencies of occurrence could help the interventional radiologist or oncologist as the root of the right inferior phrenic artery needs to be found out during transcatheter embolization of hepatocellular carcinoma and other hepatic neoplasms. It is well known fact that the origin of inferior phrenic artery shows variations and the purpose of the present study is to verify these variations so that such findings could be useful during treatment of hepatic neoplasm, management of liver transplants and biliary tract surgery, evaluating the efficacy and safety of Tans catheter oily chemo embolization technique via inferior phrenic artery.

## METHODS

The study was conducted in the anatomy department, University College of medical science Delhi over a period of 5 years (2009-2014). The sample comprised of 30 formaline-fixed cadavers, ages ranging from 22 years to 80 years (24 males and 6 females). According to Cunningham's Manual of Practical Anatomy[9] routine manual dissection was done to open the abdomen. The abdominal cavity was opened by a cruciform incision passing through the whole thickness of the anterior abdominal wall. Flaps were reflected. After removal of the lesser omentum, the proximal part of abdominal aorta and its branches were traced out. Later, after the removal of the stomach and pancreas, the origins of the inferior phrenic artery were confirmed. The frequency and anatomical pattern of the origin of the right and left inferior phrenic arteries were observed and noted, important findings were photographed.

## RESULTS

In the present study, the origin of the artery though variable, there was a noticeable tendency for the origin of inferior phrenic arteries of the right and left sides to be symmetrical and most commonly from the abdominal aorta independently.

**Table 1: Incidence of source of origin of inferior phrenic artery in the present study.**

| Source of origin of IPA | Independent origin | |
|---|---|---|
| | **Right** | **Left** |
| Abdominal aorta | 34 (94.4%) | 35 (97.2%) |
| Other sources | 2 (5.55%) | 1 (2.77%) |
| | LHA-1 | - |
| | LGA-1 | LGA-1 |

IPA-Inferior phrenic artery, LHA-Left hepatic artery, LGA-Left gastric artery

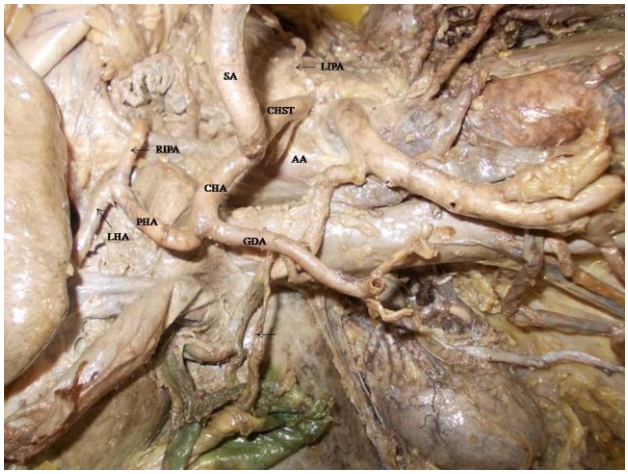


**Figure 1: Showing right inferior phrenic artery (RIPA) arising from left hepatic artery (LHA). List of abbreviations used: AA-Abdominal aorta, CHST-Common hepatospleenic trunk, SA-Spleenic artery, CHA- Common hepatic artery, GDA-Gastro duodenal artery, PHA-Proper hepatic artery, LIPA- Left inferior phrenic artery.**

It is clear from Table 1 that out of the 72 arteries studied 69 (95.83%) had normal origin from aorta (Figure 3). Of these 69 arteries, 34 (94.4%) were of the right side (right inferior phrenic artery) and 35 (97.2%) were of the left

side (left inferior phrenic artery). Other sources of origin were seen in 5.55% cases. Left hepatic artery was seen as the source of origin on right side (right inferior phrenic artery) in one case (Figure 1) while in second case left gastric artery was the source on both the right (right inferior phrenic artery) and left side (left inferior phrenic artery) (Figure 2).

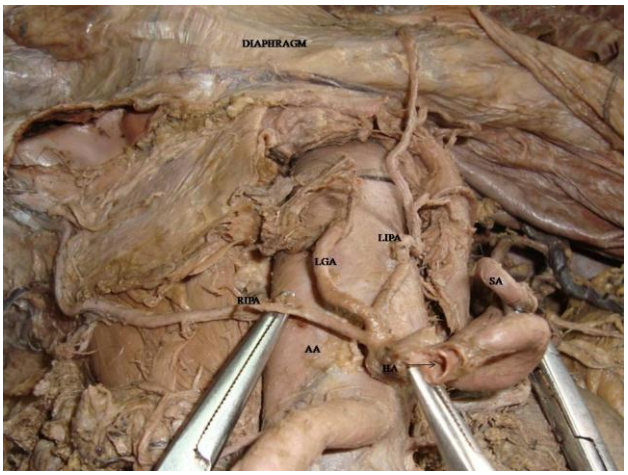


**Figure 2: Right inferior phrenic artery (RIPA) and left inferior phrenic artery (LIPA) arising from left gastric artery (LGA). List of abbreviations used: SA-Spleenic artery, HA-Hepatic artery, AA-Abdominal aorta.**

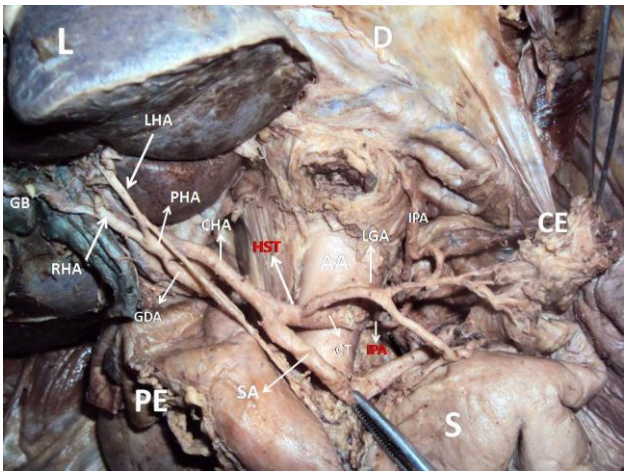


**Figure 3: Origin of Inferior phrenic arteries (IPA) from abdominal aorta (AA). List of abbreviations used: CT-Coeliac trunk, LGA-Left gastric artery, SA-Spleenic artery, HST-Hepatospleenic trunk, CHT-Common hepatic artery, GD-Gastro duodenal artery, PHA-Proper hepatic artery, RHA-Right hepatic artery, LHA-Left hepatic artery, GB-Gallbladder, L-Liver, S-Stomach, PE-Pyloric end, CE-Cardiac end of stomach, D-Diaphragm.**

***Embryological basis***

During fetal development celiac trunk and inferior phrenic artery are derived from six pairs of ventral splanchnic branches. These branches span and disappear, however the persistence of longitudinal channels between these primitive vessels may lead to vascular variations. Inferior phrenic artery is said to be formed by the persistent superior artery of irregular series of arterial vessels called Rete arteriosus urogenitale.[10]

## DISCUSSION

According to the English edition of Gray's Anatomy,[11] inferior phrenic arteries originate from the aorta or celiac trunk, variably from common trunks and possibly from the renal artery. The American edition of Gray's Anatomy[12] described origins from both the celiac trunk and aorta, as well as common trunk origins and mentioned alternative origins, including the renal or accessory renal arteries, the left gastric, hepatic, and gonadal arteries. But the statistical information regarding origin of either the right inferior phrenic artery or left inferior phrenic artery was not provided by any of these references. Due to the lack of information regarding inferior phrenic arteries, a more definitive study is necessary, to find out its clinical applications and to provide additional data to existing anatomical literature.

Gokan et al.[8] by a computed tomography study found that in 46% of cases RIPA arose from aorta and in 52% of cases origin was celiac trunk on left side. They also noted alternative origins (left gastric, hepatic, superior mesenteric, and spermatic), stating that such origins occurred with <4% frequency on either the right or left side. Pulakunta T et al.[13] did a study on 32 cadavers observed the origin of the inferior phrenic arteries from the celiac trunk in two specimens (6.25%), one from the left gastric artery (3.125%) and one from the right renal artery (3.125%) out of the 32 cadavers. In the remaining 28 specimens it had its normal origin from the abdominal aorta. Loukas et al.[14] studied 300 cadavers and observed that the origin of right IPA is from: a) celiac trunk in 40% of the specimens; b) aorta in 38%; c) renal in 17%; d) left gastric in 3%; and e) hepatic artery proper in 2% of the specimens. The origin of left inferior phrenic artery is from: a) celiac trunk in 47%; b) aorta in 45%; c) renal in 5%; d) left gastric in 2%; and e) hepatic artery proper in 1% of the specimens.

Out of 68 cadavers studied, Piao DX et al.[15] mentioned the majority of the origin of inferior phrenic artery is from the aorta (61.6%) and the origins from either renal, left gastric or middle adrenal arteries were also observed.

Pick & Anson[16] studied the inferior phrenic artery origins using 200 cadavers and noted that most common sources are aorta and celiac artery (45.1 and 47.8%, respectively). They reported that <7% originated variably from the renal (5.8%), left gastric (2.3%) or hepatic arteries (0.3%).

Table 2 shows our study correlates with the studies of Piao DX et al.[15] and Thejodhar Pulakunta[13] stating that

inferior phrenic artery originate most commonly from aorta and with studies of Pick & Anson,[16] Loukas et al.,[14] Gokan et al.[8] as the origin from left hepatic and gastric artery (Figure 1, 2) were also observed but differs from these studies with respect to the origin of inferior phrenic artery from renal arteries. Pick & Anson,[16] Loukas et al.,[14] Gokan et al.[8] reported celiac artery to be the commonest source of origin, such finding was not observed in our study.

**Table 2: Comparison of the percentage of origins of inferior phrenic artery in the present study with those of earlier studies.**

| Source of origin of IPA | Pulakunta et al.[13] (32 cadavers) | Loukas et al[14] (300 cadavers) | | Pick & Anson[16] (200 cadavers) | Present study (30 cadavers) | |
|---|---|---|---|---|---|---|
| | | RIPA | LIPA | | RIPA | LIPA |
| Aorta | 87.5% | 38% | 45% | 45.1% | 34 cases (94.4%) | 35 cases (97.2%) |
| Celiac trunk | 6.25% | 40% | 47% | 47.8%, | - | - |
| Hepatic artery | - | 2% | 0.5% | 0.3% | 1 case (LHA) | - |
| Left gastric artery | 3.125% | 3% | 2% | 2.3% | 1 case | 1 case |

RIPA-Right inferior phrenic artery; LIPA-Left inferior phrenic artery; LHA-Left hepatic artery

Our study is concluded with the fact that more common origin of inferior phrenic artery is from abdominal aorta independently on both the sides. Origin from other sources like left hepatic and gastric arteries were also observed. The knowledge of the arterial anatomic variations is very important for the clinical, radiological and surgical diagnosis.[17]

Extensive knowledge of all possible variations of inferior phrenic artery origin will provide valuable data to researchers, clinicians and anatomists alike. These data will useful for the management of liver transplants and biliary tract surgery,[13] enhancing the understanding of both the specific anatomy of the inferior phrenic arteries as well as their potential significance in supplying hepatocellular carcinomas and other liver tumors, primary or metastatic, such as cholangiocarcinoma, hepatoblastoma and subcapsular adenoma.[18] It is also useful in evaluating the efficacy and safety of Tans catheter oily chemo embolization technique via inferior phrenic artery, discussion and treatment of other hepatic, suprarenal or even diaphragmatic lesions.[14] The left inferior phrenic artery is major source of blood supply during occlusion of right and left gastric arteries.[13]

Information of inferior phrenic artery variations is necessary to avoid unintentional sectioning of these small calibre arteries, as it may be seen during decompression in compression syndrome of the celiac trunk by the median arcuate ligament.[19]

*Funding: No funding sources*
*Conflict of interest: None declared*
*Ethical approval: Not required*

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DOI: 10.5455/2320-6012.ijrms20150151
**Cite this article as:** Thamke S, Rani P. Normal and variant origin and branching pattern of inferior phrenic arteries and their clinical implications: a cadaveric study. Int J Res Med Sci 2015;3:282-6.