

**Original article:**

## **Embryological basis of variation of origin of inferior phrenic artery-a cadaveric study in South Bengal**

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### **ABSTRACT**

**Introduction:** A few studies are available regarding variations of inferior phrenic arteries. Present study focuses the distributions, variations, embryological basis and origin of inferior phrenic arteries.

**Methods:** The study was conducted in NRS Medical College. 25 adult human cadavers were manually dissected and variations of inferior phrenic arteries were recorded in both sides.

**Observations and Results:** 20% cases abdominal aorta had a common trunk which bifurcated into right and left inferior phrenic arteries. In another 20% cadavers inferior phrenic artery arose from the celiac trunk. Renal arteries were the source in 4% cases. Rest of the cadavers, as usual inferior phrenic arteries were paired lateral branches of abdominal aorta.

**Conclusion:** The inferior phrenic artery is the most common source of extra-hepatic collateral blood supply for hepatocellular carcinoma. Clinical implications of variation in its origin have been reviewed in this article.

**KEY WORDS** –Inferior phrenic artery, Coeliac Trunk, Abdominal Aorta

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### **INTRODUCTION**

The diaphragm is perfused by a pair of inferior phrenic arteries (IPA). It arises from the aorta or from a common aortic origin with the celiac trunk, from celiac trunk itself or from the renal artery<sup>1</sup>. Near the central tendon of the diaphragm it divides into medial and lateral branches. Each inferior phrenic has small suprarenal branches and provide little blood to the capsule of the liver and spleen. IPA is both a somatic and visceral artery. The left inferior phrenic artery (LIPA) is in close proximity to the esophageal

hiatus and may provide an ascending branch to esophagus or stomach<sup>2</sup>. The IPA is the most common source of extra-hepatic collateral blood supply for hepatocellular carcinoma (HCC) and frequently supplies HCCs located in the bare area of the liver<sup>3</sup>. The importance of such knowledge lies in the fact that an unresectable hepatocellular carcinoma can be treated by transcatheter embolization of not only the right or left hepatic arteries, but also by embolization of a right inferior phrenic artery (RIPA), if involved<sup>4</sup>. Radiologists must be familiar with the normal

spectrum of IPA anatomy so that detection and adequate interventional management can be achieved when pathologic conditions related to the IPA are presented. The present study is a humble approach to record the variations and apply the knowledge clinically.

**MATERIALS AND METHODS**

The study was conducted with 25 adult well-embalmed human cadavers from Department of Anatomy, Nil Ratan Sircar Medical College, Kolkata, West Bengal for a period of two years from 2015-16. Amongst them 5 were females and rest 20 were males. Post mortem cadavers were excluded from study. The aim of the study was to dissect the inferior phrenic artery from its origin and record the variations as there is paucity of information regarding its mode of origin. The abdominal cavity was opened by a cruciate incision. Flaps were reflected. The abdominal viscera i.e. stomach, intestines, liver, pancreas and spleen were systematically removed according to Cunningham’s Manual of Practical Anatomy<sup>5</sup>. The gastro-esophageal junction was kept intact as this part is supplied by IPA. The crus of the

diaphragm was mobilized and the inferior phrenic arteries were traced from their origin and cleaned. Variations of the mode of origin and branching pattern were noted and photographs taken during different steps of dissection. Age and sex was not taken into consideration while computing the results.

**OBSERVATIONS AND RESULTS**

In the present study we found myriad variations of the source of origin of inferior phrenic arteries. The most common source of origin being the abdominal aorta (AA) independently on both sides as paired lateral branches. But in many cases the origin of RIPA and LIPA was found to be asymmetrical. Table 1 shows the variations of origin as found in our study. Fig 1 depicts that RIPA arose from the right renal artery as a common trunk with middle and inferior suprarenal artery. RIPA itself provided the right suprarenal branch. LIPA originated from the AA. Fig 2 shows that LIPA arising directly from the celiac trunk (CT) and RIPA from AA. Fig 3 points the common trunk arising from the AA and then dividing into RIPA & LIPA.

Table 1-SOURCES OF ORIGIN OF INFERIOR PHRENIC ARTERY

PARENT ARTERY	NO OF CASES	PERCENTAGE %
AA as common trunk	5	20
AA on the Right & CT on the Left	5	20
Renal	1	4
AA as paired independent lateral branches	14	56

Table 2-COMPARISON OF THE SOURCE OF INCIDENCE OF INFERIOR PHRENIC ARTERY

VARIATION TYPE	GREIG & CO- WORKERS(%)	PRESENT STUDY(%)
CT bilaterally	20.9	-
AA as common trunk	18.1	20
Left- CT,Right- AA	14.8	20
AA bilaterally as separate branches	12.7	56
CT as common trunk	12.2	-
Left-AA,Right-CT	7.5	-
Left-CT,Right- Renal	3.8	-
Left-AA,Right- Renal	3.1	4

### DISCUSSION

The anatomy of IPA is often overlooked in dissection of the abdomen. Adequate literature is unavailable. So our aim was to have a detailed study regarding the source of origin and supply of IPA to enlighten the knowledge. Table 2 shows the comparison of the present study with previous studies.

The present study reveals that IPA most commonly arises from the AA(56%). This corroborates with the study of Akhilandeswari B et al <sup>6</sup> (53.125%) and Wadhwa A et al <sup>7</sup> (55%). But the value is less in the study of Gokan et al <sup>8</sup> (46%) and Loukas et al <sup>9</sup> (38%) and much higher in Pulakunta et al <sup>10</sup> (87.5%). The fact that IPA arises as a common trunk from the AA (20%) is very close to the study by Greig & co workers <sup>11</sup> (18.1%). The commonest variety where IPA is independently arising from the AA(56%) does not match with Greig & co workers <sup>11</sup> (12.7%) probably due to racial variations.

CT was the second common source of origin of IPA and mostly on the left side. Our finding(20%) matches closely with Greig & co-workers <sup>11</sup> (14.5%). Again, renal artery giving rise to IPA was on the right side(4%) and was similar in comparison to Greig & co workers <sup>11</sup> (3.1%) and Pulakunta et al <sup>10</sup>

(3.125%). The knowledge of this type of variation shows that surgeons must be cautious to avoid unintentional sectioning of small caliber arteries, as it may occur during the celiac artery decompression in the compression syndrome of the celiac trunk by the median arcuate ligament <sup>7</sup>. The present study could not unfold any other source of origin of IPA like suprarenal, left gastric, superior mesenteric etc.

Those instances in which IPA arises from the renal artery, suprarenal arteries are usually derived from renal sources. In the present study RIPA gave rise to the superior suprarenal branch, middle and inferior suprarenal arising as a common trunk from right renal artery(Fig 1). This fact may be of surgical importance, in clamping renal pedicle, in nephrectomy, when the entire blood supply of the suprarenal gland on that side could be ligated by tying the renal artery proximal to its inferior phrenic branch. Fortunately with the phrenic artery arising from the renal artery more commonly on the right side, the proximal segment of right renal artery, where the phrenic usually takes root, is covered by inferior vena cava anteriorly and thus preventing them from trauma in manipulation of renal pedicle. Contrary, the hazard is greater on the left side <sup>12</sup>.

The RIPA is one of the chief postoperative bleeding sources in liver transplant recipients. During liver transplantation, ligation of the RIPA is necessary for hepatectomy in the recipient and for right hepatic lobectomy in a living donor. If the ligation of this artery is not maintained adequately, bleeding from the IPA can occur after liver transplantation<sup>13</sup>. Apart from being the main arterial supply to the diaphragm, RIPA and LIPA, are extrahepatic collateral arterial pathways that supply hepatic malignancies, because they neighbor hepatic segments as they traverse the bare area of the liver<sup>14,15</sup>. In hepatic arterial occlusion or in cases where the hepatoma is close to the bare area of liver, IPA angiography is done. Selective transcatheter arterial chemoembolization (TACE) from IPA is preferred. In case where proximal IPA is used for TACE, complications such as pleural effusion, basal atelectasis, weakness of diaphragm, and gastroesophageal ulcerations can occur<sup>16</sup>. There have been reports of gastroesophageal bleeding and Mallory-Weiss tear due to bleeding from LIPA<sup>17</sup>.

Variations regarding the lateral branches of the abdominal aorta can be explained with the ladder theory proposed by Felix<sup>18</sup>. This theory states that the IPAs develop from the cranial group of the lateral mesonephric arteries and variations between other lateral branches (such as the middle suprarenal, renal and gonadal arteries) are possible. However, the coeliac origin and the common trunk of the IPAs originating from the midline aorta as an anterior branch cannot be explained with this theory. According to Isogai et al<sup>19</sup>, at embryonic day 14.0, a few branches from the gonadal artery and/or the abdominal aorta supply the cranial half of the para-aortic ridge which is the adrenal primordium. The most cranial part of these adrenal arteries, which are

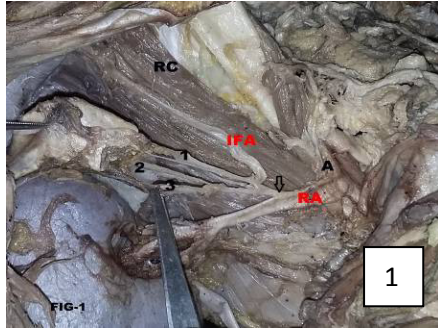
the prospective IPAs, reaches the diaphragm at the embryonic day 14.3. By the 15th day, the adrenal arteries and eventually the IPAs establish their definitive branching pattern of the adult<sup>19</sup>. This new perspective might provide an explanation for the coeliac origin of the IPAs and even its origin as a common trunk from the posterior aspect of the aorta. However, there is not enough evidence in the literature that can enlighten the separate origins of the branches of the IPAs and why this situation is observed on the left side alone, as well as the relocation of the ascending branch anterior to the esophagus in most of these cases<sup>20</sup>.

Another possible embryological explanation for coeliac origin of IPA may be as follows: The dorsal aorta gives three types of branches-ventral, lateral splanchnic, and somatic intersegmental branches. With the fusion of dorsal aortae, the ventral branches are fused and form a series of unpaired segmental vessels, which run forwards through the dorsal mesentery of the primitive gut and divide into two transverse, ascending and descending branches along the dorsal aspect of the gut. These vessels form dorsal and ventral longitudinal anastomotic channels (FIG 4). With the advent of this, the ventral splanchnic branches are withdrawn leaving behind three trunks which persist as coeliac, superior & inferior mesenteric arteries<sup>21</sup>. Occasionally there are communications between ventral and lateral splanchnic branches. The portion of lateral branch from origin to communication may disappear and it seems that IPA is originating from coeliac artery (FIG 5).

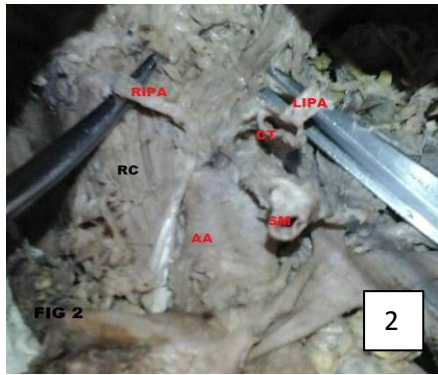
## CONCLUSION

Recognition of variations enables clinicians to distinguish features which merit further investigations or treatment from those which do not.

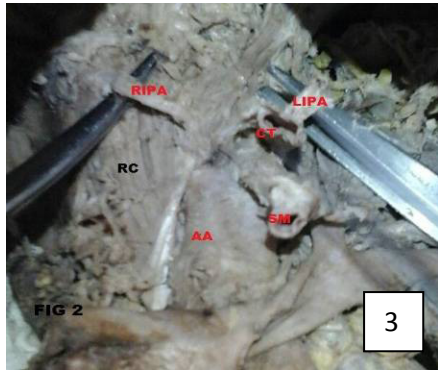
Radiologists must be familiar with the normal spectrum of IPA anatomy. Hope this study provides additional anatomical data of the variation of IPA for future studies.



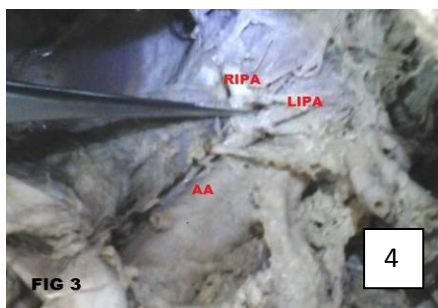
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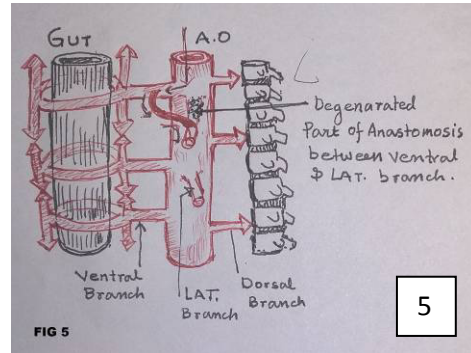
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FIG 1 : A- Abdominal aorta,RA- right renal artery,RC- Right crus of diaphragm, IFA- right inferior phrenic artery,Black Arrow- Common trunk arising from right renal artery,1- superior suprarenal artery,branch of inferior phrenic,2 & 3- middle and inferior suprarenal arising as a common stem from right renal artery

FIG 2 : AA- Abdominal aorta,SM- Superior mesenteric artery, CT- Coeliac trunk ,RIPA- Right inferior phrenic artery,LIPA- Left inferior phrenic artery,RC- Right crus of diaphragm

FIG 3 : AA- Abdominal aorta ,RIPA- Right inferior phrenic artery,LIPA- Left inferior phrenic artery,forceps holding the common trunk of inferior phrenic artery arising from abdominal aorta

FIG 4 : Stage I of embryologic origin of IPA from CT .AO- Abdominal Aorta,Gut- Developing gut tube

FIG 5: Stage II embryologic origin of IPA from CT. AO- Abdominal Aorta,Gut- Developing gut tube

**ABBREVIATIONS:**

- IPA-Inferior Phrenic Artery
- LIPA-Left Inferior Phrenic Artery
- HCC-Hepatocellular Carcinoma
- RIPA-Right inferior Phrenic artery
- AA-Abdominal Aorta
- CT-Celiac Trunk
- TACE-Transcatheter Arterial Chemoembolization

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