

# Anatomical Variation of the Right Inferior Phrenic Artery in Local Population on Arterial Phase CT

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## ABSTRACT

**Objective:** To assess the frequency of the anatomical variation of the right inferior phrenic artery (RIPA) on arterial phase CT in a subset of the local population in a tertiary care private hospital.

**Study Design:** A descriptive, cross-sectional study.

**Place and Duration of the Study:** Department of Radiology, Shifa International Hospital, Islamabad, Pakistan, from August to December, 2023.

**Methodology:** Two hundred and fifty patients between 12 and 70 years of age who underwent arterial phase CT were evaluated in this study. Demographic information and arterial phase CT images, processed with 1mm slice thickness, were comprehensively analysed to delineate anatomical variations in the RIPA origin. The arterial origin points were systematically classified into six distinct anatomical categories: Abdominal aorta, coeliac trunk, right renal artery, left gastric artery, accessory right renal artery, and splenic artery. The RIPA originating from a common trunk with the left inferior phrenic artery was excluded from the study. The study was reviewed and approved by the Institutional Review Board and Ethical Committee of the Shifa International Hospital, Islamabad, Pakistan. Informed consent was obtained from all participants prior to the data collection. Descriptive statistics (frequency and percentages) were used to determine qualitative variables.

**Results:** The study cohort had a mean age of  $40.42 \pm 14.81$  years, with a notable male predominance of 65.6%. Anatomical variations of the RIPA demonstrated the abdominal aorta as the most common origin, followed sequentially by the coeliac trunk, right renal artery, left gastric artery, accessory right renal artery, and splenic artery.

**Conclusion:** This study emphasises the key anatomical variations in RIPA, primarily arising from the abdominal aorta and coeliac trunk.

**Key Words:** Arterial phase CT, Right inferior phrenic artery, Abdominal aorta, Coeliac artery, Anatomical variations.

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## INTRODUCTION

Anatomical variation in the origin of the right inferior phrenic artery (RIPA) is an important consideration when interpreting arterial-phase CT scans, as such variation might affect diagnostic and therapeutic approaches.<sup>1</sup> Usually, the RIPA arises from the coeliac trunk or the superior mesenteric artery (SMA) branches of the abdominal aorta; however, in some individuals, it may originate from other structures, such as the aorta or renal artery.<sup>2</sup> Knowing this variation is crucial for surgeons and radiologists because an abnormal RIPA can lead to modifications of vascular anatomy involving the diaphragm, liver, and surrounding structures, complicating surgical interventions such as hepatic resections, renal transplantations, or repairs of abdominal aortic aneurysms.<sup>3</sup>

Precise identification during the arterial phase of the CT, which delineates blood vessels due to the contrast medium, is important for appropriate preoperative planning.<sup>4</sup> The RIPA is the most common extrahepatic supply to hepatocellular carcinoma (HCC).<sup>5-8</sup>

At arterial phase CT, the RIPA appears as a small vessel that supplies the diaphragm, although its exact course may vary.<sup>9</sup> In cases of variation, the RIPA might originate directly from the aorta or renal artery, resulting in an altered route and vascular distribution.<sup>1</sup> These variations are common and may give rise to diagnostic doubts if not studied with due care, especially in the study of pathologies such as hepatic tumours, diaphragmatic hernias, or vascular malformations. Therefore, understanding the atypical origins and courses in the arterial phase is crucial for making good clinical decisions.<sup>10</sup>

Typically, a high-resolution CT taken during the arterial phase provides sharp and contrastingly-enhanced visualisations of vascular structures in the RIPA variations.<sup>11</sup> Deviation from normal RIPA anatomy is best assessed in studies where the contrast medium is optimally timed to outline arterial structures.<sup>12</sup> This becomes more important when interventions such as embolisation are planned. In such interventions detailed knowledge about vascular anatomy is crucial to avoid

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inadvertent injury to the artery and its ramifications. This may also provide clues regarding various anomalies of the RIPA, as knowledge of such variations in the artery would thus provide ways and means of diagnosing related anatomical anomalies, generally leading to improvement of diagnostic and therapeutic outcomes.<sup>13</sup>

A study by Ekingen *et al.* reported that RIPA originated from the non-common trunk from the abdominal aorta in 258 (42.36%) patients, coeliac trunk in 205 (33.66%), left gastric artery in 36 (6%), and right renal artery in 91 (14.94%).<sup>14</sup>

Studying the frequency of anatomical variation of the RIPA on arterial-phase CT in the local population is vital for improving preoperative planning, surgical precision, and diagnostic accuracy. Understanding these variations helps reduce vascular injury during procedures and allows for more tailored medical approaches, enhancing overall clinical outcomes.

The objective of this study was to assess the frequency of anatomical variations in the origin of RIPA on arterial phase CT in the local population.

## METHODOLOGY

A cross-sectional observational study was performed at the Department of Radiology, Shifa International Hospital, Islamabad, Pakistan, from August to December, 2023, encompassing both inpatient and outpatient populations. The sample was collected through consecutive sampling. A total sample size of 250 was determined utilising the World Health Organization (WHO) sample size calculator, employing a 95% confidence interval and an anticipated population proportion of 6%,<sup>10</sup> and a 3% margin of error. Inclusion criteria were patients of both genders, aged 12-70 years, referred for arterial phase CT, excluding those who had undergone hepatectomy or liver transplantation. The RIPA originating from a common trunk with the left inferior phrenic artery was also excluded from the study. The study was reviewed and approved by the Institutional Review Board and Ethical Committee of the Shifa International Hospital, Islamabad, Pakistan. After obtaining informed consent from patients, demographic data and arterial phase CT images with 1 mm slice thickness were collected and assessed by a trainee radiologist. The RIPA was defined as a single vessel that typically arises from the abdominal aorta immediately below the diaphragm. Variations in the origin of the RIPA were identified on arterial-phase CT as arterially enhancing vessels arising from various origins, such as aorta, coeliac artery, right renal artery, left gastric artery, or other origins.

Data analysis was performed using the SPSS version 25. Quantitative variables such as age and weight were expressed as mean  $\pm$  standard deviation, while qualitative variables such as gender and origin of RIPA were expressed as frequency and percentage. The Chi-square test was applied, and a p-value of  $\leq 0.05$  was considered statistically significant.

## RESULTS

In this study involving 250 patients, the demographic characteristics revealed a mean age of  $40.42 \pm 14.81$  years and a mean weight of  $73.23 \pm 10.96$  kg. Gender distribution demonstrated a predominance of male participants, with 164 (65.6%) males compared to 86 (34.4%) females, as shown in Table I.

Anatomical variations of the RIPA revealed a hierarchical distribution of origin points. The abdominal aorta emerged as the predominant source, accounting for 104 (41.6%) patients (Figure 1), followed by the coeliac trunk in 72 (28.8%) patients (Figure 2). The right renal artery was identified as the origin in 40 (16%) patients (Figure 3), while the left gastric artery was observed in 19 (7.6%) patients. Less frequently, the accessory right renal artery was the source in 3 (1.2%) patients, and the splenic artery was the least common origin, observed in 2 (0.8%) patients, as detailed in Table II.

**Table I: Demographic characteristics of patients (n = 250).**

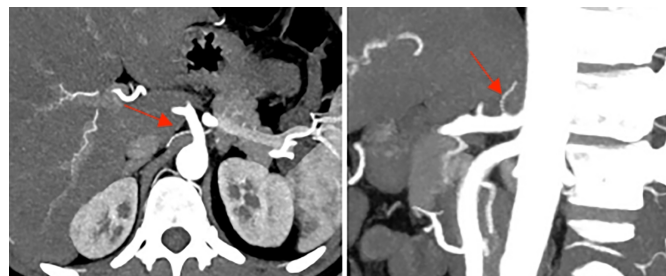
Demographics	Mean $\pm$ SD
Age (years)	40.416 $\pm$ 14.81
Weight (Kg)	73.232 $\pm$ 10.96
Gender	n (%)
Males	164 (65.6)
Females	86 (34.4)

**Table II: Prevalence and proportion of patients categorised by anatomical variations of the right inferior phrenic artery.**

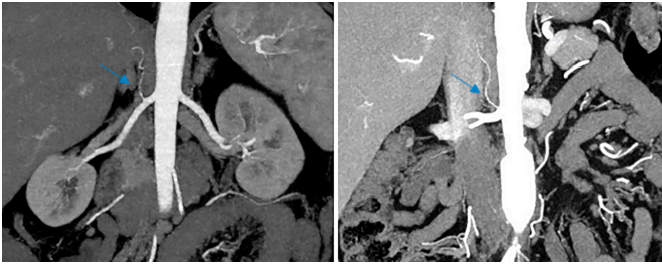
Anatomical variations of the right inferior phrenic artery	Frequencies	Percentages (%)
Abdominal aorta	104	41.6%
Coeliac trunk	72	28.8%
Right renal artery	40	16%
Left gastric artery	19	7.6%
Accessory right renal artery	3	1.2%
Splenic artery	2	0.8%



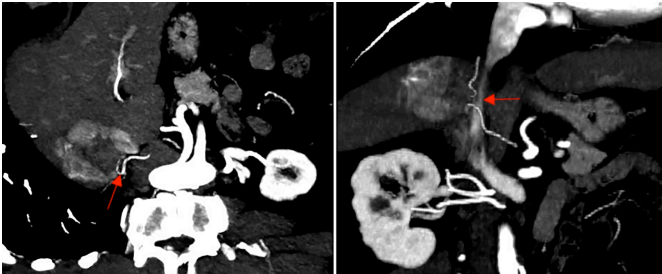
**Figure 1: CT angiography MIP images show the right inferior phrenic artery (RIPA, yellow arrow) originating from the aorta.**



**Figure 2: CT angiography MIP images show the right inferior phrenic artery (RIPA, red arrow) arising from the coeliac artery.**



**Figure 3:** CT angiography MIP images show the right inferior phrenic artery (RIPA, blue arrow) originating from the right renal artery in two different patients.



**Figure 4:** CT angiography MIP images show the right inferior phrenic artery (RIPA, red arrow) as one of the branches supplying HCC.

## DISCUSSION

The present study provides a comprehensive investigation into the anatomical variations of the RIPA through the arterial-phase CT imaging, offering valuable insights into the vascular anatomy of a local population cohort. The research encompassed 250 patients, with a mean age of  $40.42 \pm 14.81$  years and a mean body weight of  $73.23 \pm 10.96$  kg, predominantly male (65.6%), which establishes a robust demographic foundation for the anatomical analysis.

Meticulous anatomical characterisation of RIPA origins unveils a sophisticated vascular architectural complexity with profound clinical significance. These intricate variations critically inform interventional strategies, particularly in specialised procedures such as transcatheter embolisation for HCC, complex upper abdominal surgical interventions, and comprehensive trauma management protocols. This investigation, complemented by a robust corpus of contemporary research, systematically elucidates the multifaceted origin patterns of RIPA, providing nuanced insights into vascular morphological diversity.

In this study, the RIPA most frequently originated from the abdominal aorta in 104 (41.6%) patients, followed by the coeliac trunk in 72 (28.8%) patients, the right renal artery in 40 (16%) patients, the left gastric artery in 19 (7.6%) patients, the accessory right renal artery in 3 (1.2%) patients, and the splenic artery in 2 (0.8%) patients. These results are consistent with the findings of Shefna *et al.*,<sup>15</sup> who identified the aortic origin as most common (53.8%), followed by the coeliac trunk (36.2%). Whitley *et al.* reported pooled prevalences of 49.6% and 35.7% for the aorta and coeliac trunk origins of the RIPA, respectively.<sup>1</sup> The study by Chandrachari *et al.* further corroborates these observations, identifying the abdominal aorta as

the source of the RIPA in 84% of cases, with smaller proportions originating from the coeliac trunk (10%), renal artery (2%), and accessory renal artery (2%).<sup>16</sup> Given the role of RIPA as an extra-hepatic collateral supply to HCC (Figure 4) and their involvement in adrenal and hepatic lesions, these findings emphasise the relevance of such variations in the interventional radiology and surgery.

Kimura *et al.* in a study of 178 patients, observed that 57% of RIPA originated from the aorta, 30% from the coeliac artery, 11% from the right renal artery, and 2% from the left gastric artery.<sup>17</sup> Variations in RIPA origin were significantly influenced by coeliac axis anomalies.<sup>18</sup>

Contrary to these results, a study conducted by Pavlov *et al.* revealed coeliac trunk (53.6%) as the origin of RIPA followed by abdominal aorta (29.8%).<sup>19</sup>

These findings provide critical insights into the anatomical variability of RIPA, which holds substantial clinical relevance across multiple disciplines. Understanding the prevalence and variation in the origins of RIPA aids in minimising complications during interventional procedures, such as transarterial chemo-embolisation (TACE) for HCC, where the RIPA frequently serves as a collateral blood supplier to liver tumours.<sup>20</sup> Moreover, precise knowledge of these variations enhances the safety and efficacy of upper abdominal surgeries, including hepatic transplantation and adrenal gland interventions, by preventing inadvertent vascular damage.

Limitations of this study are that it is a retrospective, single-centred study and has a limited sample size. In future, similar studies can be conducted in multiple centres with greater sample size.

## CONCLUSION

This study illuminates the substantial anatomical heterogeneity in RIPA origins, demonstrating the predominant emergence from the abdominal aorta and coeliac trunk as the primary vascular contributors. These findings underscore the critical importance of comprehensive preoperative vascular mapping and anatomical awareness in surgical and interventional planning.

### ETHICAL APPROVAL:

The study was reviewed and approved by the Institutional Review Board and Ethical Committee of the Shifa International Hospital, Islamabad, Pakistan.

### PATIENTS' CONSENT:

Informed consent was obtained from all the participants prior to the data collection.

### COMPETING INTEREST:

The authors declared no conflict of interest.

### AUTHORS' CONTRIBUTION:

AS: Conception of the study, manuscript drafting, and acquisition of the data.



AIR: Manuscript drafting, data analysis, and data interpretation.  
 US: Acquisition and interpretation of the data.  
 All authors approved the final version of the manuscript to be published.

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