

Retrospective Analysis of Hepatic Vein Opening Variations into the Inferior Vena Cava Within the Diaphragm: A Study of 17 Fetal Cases**Pallavi Priyavadini¹, Rashmi Kumari², Seema Tabassum³, Sudhir Kumar Karn⁴**¹Tutor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India²Tutor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India³Professor, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India⁴Professor and HOD, Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India

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Abstract:**Background:** The hepatic veins (HVs) normally drain into the inferior vena cava (IVC) just below the diaphragm, but developmental remodeling may produce intra-diaphragmatic variations with clinical and embryological relevance.**Aim:** To retrospectively analyze patterns and morphometry of fetal hepatic vein openings into the IVC within the diaphragm.**Methodology:** A descriptive anatomical study was conducted at Darbhanga Medical College and Hospital on 17 preserved fetuses (21–40 weeks gestation). Thoraco-abdominal dissection exposed the diaphragm, IVC, and hepatic veins. Accessory foramina were identified and measured using a digital caliper. Descriptive statistics were applied.**Results:** Three patterns were observed: Type 1 single foramen (11 cases), Type 2 double foramina (3 cases), and Type 3 triple foramina (3 cases). External fetal parameters correlated positively with gestational age. Caval opening diameter increased from 2–7 mm, while hepatic venous foramina enlarged proportionally (1.5–6.5 mm in Type 1; up to 5 mm in Type 3). Greater number of openings corresponded with larger diameters.**Conclusion:** Fetal hepatic venous entry into the IVC within the diaphragm shows organized developmental variability with progressive enlargement and increasing complexity, representing transitional stages toward postnatal anatomy and holding significance for fetal imaging and hepatodiaphragmatic surgery.**Keywords:** Hepatic Veins, Inferior Vena Cava, Diaphragm, Fetal Anatomy, Accessory Foramina, Venous Development, Morphometry.**DOI:** 10.25258/Ijpqa.17.1.76

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Introduction

Liver is a very vascular gland whose hematologic, metabolic and excretion activities rely upon a well-structured system of venous drainage. The hepatic veins (HVs) take venous blood of the liver to the inferior vena cava (IVC) [1]. The terminal parts of these veins cross the superior posterior side of the liver and, as a rule, drain into the IVC just below the diaphragm. The anatomical relationship between the hepatic veins, the caval opening and the intra-diaphragmatic element of the IVC is of specific developmental and clinical significance because of the structural border of the two cavities lying in the diaphragm.

Normally three HVs have been found to leave the liver however deviations in numbers are not uncommon [2]. They are traditionally called the right hepatic vein, middle (intermediate) hepatic vein and the left hepatic vein. Each hepatic segment of each drain serves functionally differentiated segments based on the principles of portal segmentation. Nevertheless, even in the case of normal physiological conditions, hepatic venous architecture exhibits high levels of diversity. In other cases, the hepatic vein on the right is single and left and intermediate hepatic veins converge to create a common trunk [3]. In other people two trunks can be observed in lieu of three, or several tiny venous fissures can take the place of one large one. This heterogeneity indicates

the complicated embryologic origin of the hepatic venous system of the vitelline venous system and its remodelling throughout the fetus development.

The HVs have also been reported to have an accessory vein (accessory hepatic vein) running alongside [4] it. These accessory hepatic drains often empty segments VI or VII directly into the IVC below the primary hepatic venous confluence, but location and caliber are both typically variable. The importance of accessory hepatic veins especially in surgery is due to the fact that their presence can be ignored, hence causing unanticipated bleeding during hepatic resection or transplantation [5]. Regarding development, they are persistent, which reflects an insufficient regression of embryonic venous channels in the liver, which should fade away during hepatic development.

Research on the variations of the HVs which drain to the IVC, had found that the difference veins may drain out to the heart chambers directly [6] as well. These abnormal endings are significant vessels of the normal venous circulation and are typically linked with abnormal development of the systemic venous circulation. In these instances, the hepatic veins can either end up in the right atria or in infrequent instances, into alternative chambers of the heart. These unusual relationships indicate a failure in the integration of the sinu venosus and vitelline veins into the final definitive venous circulation.

The differences in which the HVs bypass the IVC to drain directly to the heart tend to arise when there is no IVC present or persist in the presence of the azygos vein and the variants go through the caval opening (CO) or through accessory foramina on the diaphragm [7]. The diaphragm thus turns out to be a crucial anatomical reference point in hepatic venous anomalies. In the midpoint tendon, the IVC and branches of the right phrenic nerve are usually found at the point of divergence of the caval opening. But there can be other apertures either congenital or acquired through which other variant venous channels can pass. The diaphragm is developed in fetus through various embryonic structures such as the septum transversum, pleuroperitoneal membranes, dorsal mesentery of the esophagus, and body wall muscles. The disrupted alignment in the development of these structures can affect the location of the IVC as well as the direction of hepatic veins.

This knowledge of these variations is significant in surgical operations between the diaphragm and the liver and fetal obstetrics. Surgical intervention such as liver transplantation, resection of hepatic tumor, repair of diaphragmatic hernias, and cardiothoracic surgery involving IVC involve accurate determination of the hepatic venous points of entry [8]. During transplant surgery, accurate reconstruction of the outflow in the vein is paramount in graft survival and intra-diaphragmatic side of liver entry of hepatic

veins may be encountered and make vascular clamping and anastomosis difficult. Likewise, in radiological procedures, the confusing aspect of the different forms of venous channels can create a misdiagnosis on imaging techniques like ultrasonography, computed tomography, and magnetic resonance angiography.

The anatomy of hepatic venous is more important in fetal medicine. The fetal circulation is vastly different compared to the postnatal circulation, especially because of the existence of ductus venosus which redirects oxygenated blood to the IVC via the umbilical vein. The changes of the hepatic venous drainage could impact the fetal hemodynamics and be linked to the birth of congenital cardiovascular malformations. The awareness of these variations when imaging a pregnant woman could help in timely detection of anomalies affecting the systemic venous system and inform the perinatal care. Moreover, the knowledge of intra-diaphragmatic relationships between the venous systems helps to interpret fetal autopsy, as well as developmental pathology [9].

Although hepatic venous variations have clinical and embryological significance, most of the literature available is based on the anatomy of the hepatic venous variations in adults or radiological observations in postnatal infants. Reports of the direct hepatic venous drainage to the heart chambers have been mostly linked to the congenital absence or obstruction of IVC. Nevertheless, there has been minimal focus on the exact topographic association between the opening of the hepatic veins and the diaphragm in the development of the fetus. The fetal stage is a period of critical development wherein the final venous routes are developed, and the differences seen during the fetal stage can be of use in understanding the pathophysiologic processes involved in the development of adult anomalies.

In the current paper, we have examined 17 fetuses with HVs in the diaphragm draining into the IVC. This study will help to fill the gap in anatomical understanding of fetal patterns of hepatic venous drainage and define a morphological foundation to explain the occurrence of congenital vascular malformations in clinical practice by specifically targeting intra-diaphragmatic venous openings.

Methodology

Study Design: This study was designed as a retrospective descriptive anatomical study analyzing variations in hepatic vein (HV) openings into the inferior vena cava (IVC) within the diaphragm in human fetuses. The study focused on morphological assessment and morphometric analysis of accessory foramina formed by hepatic veins.

Study Area: The study was conducted in the Department of Anatomy, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India

Study Duration: The study was carried out over a period of six months from May 2025 to October 2025.

Sample Size: The total sample size for the study was 17 human fetuses (N = 17). These cases demonstrated variations in hepatic vein openings into the inferior vena cava within the diaphragm and were included for detailed anatomical analysis.

Sample Population: The study population comprised 17 preserved human fetuses of varying gestational ages, approximately between 21 and 40 weeks. Both male and female fetuses were included. The specimens were available in the Department of Anatomy and were preserved for academic and research purposes. Only well-preserved fetuses with intact diaphragmatic and visceral anatomy were considered suitable for examination.

Data Collection: Data collection involved both morphologic observation and morphometric measurement. Gestational age of each fetus was determined using standard anthropometric parameters such as crown-rump length (CRL), biparietal diameter (BPD), head circumference (HC), femur length (FL), and foot length (FtL). Following age estimation, detailed external measurements were recorded. Thoraco-abdominal dissection was performed to expose the diaphragm and adjacent structures. Intra-thoracic and intra-abdominal viscera were carefully removed to clearly visualize the superior and inferior surfaces of the diaphragm. The inferior vena cava, hepatic veins, and major diaphragmatic openings including the caval opening, aortic hiatus, and esophageal hiatus were identified and examined. Particular attention was paid to accessory foramina formed by hepatic veins prior to their entry into the IVC. Measurements of the transverse and vertical diameters of these foramina were taken using a digital caliper, and the mean diameter was calculated using the formula: (transverse diameter + vertical diameter) / 2. All findings were systematically recorded and documented.

Inclusion Criteria

- Human fetuses with intact diaphragm and abdominal/thoracic viscera.
- Fetuses with clearly identifiable hepatic veins and inferior vena cava.
- Fetuses demonstrating variations in hepatic vein openings into the IVC within the diaphragm.

Exclusion Criteria

- Fetuses with gross congenital malformations affecting the diaphragm or liver.
- Damaged or poorly preserved specimens.
- Specimens with incomplete visualization of the IVC or hepatic veins.

Procedure: After selection of eligible specimens, gestational age estimation was performed using standard anthropometric measurements. Thoraco-abdominal dissection was carried out carefully to expose the diaphragm and surrounding viscera. The intra-thoracic and intra-abdominal organs were removed to allow clear visualization of the inferior vena cava, hepatic veins, and diaphragmatic openings. Variations in hepatic vein entry into the IVC were observed and documented. Accessory foramina were identified, and their transverse and vertical diameters were measured using a digital caliper. The mean diameters were calculated and recorded for analysis.

Statistical Analysis: All collected data were entered into Microsoft Excel and analyzed using appropriate statistical software. Descriptive statistics including frequency, percentage, mean, and standard deviation were calculated. Morphometric measurements were expressed as mean \pm standard deviation. Findings were presented in tabular form, and graphical representation was used where necessary. A p-value of less than 0.05 was considered statistically significant when inferential analysis was applied.”

Result

Table 1 demonstrates a consistent increase in all general external fetal parameters with advancing gestational age across all 17 fetuses. In Type 1 fetuses (n=11), crown-rump length (CRL), head circumference (HC), biparietal diameter (BPD), femur length (FL), and foot length (FtL) showed a steady progressive rise from 21 to 40 weeks, reflecting normal somatic growth. Similar age-related increases were observed in Type 2 (n=3) and Type 3 (n=3) fetuses, with measurements comparable to those of Type 1 fetuses at corresponding gestational ages. Overall, the data indicate a positive correlation between gestational age and external fetal dimensions, with no marked deviations among the three types.

Case No.	Age* (week)	Sex	CRL (mm)	HC (mm)	BPD (mm)	FL (mm)	FtL (mm)
Type 1 (n=11)							
1	21	M	185	180	48	38	39
2	23	F	215	195	52	42	44
3	25	M	240	225	60	49	50
4	27	F	260	250	68	55	56
5	29	M	275	270	72	60	62
6	31	F	295	285	76	64	66
7	33	M	315	305	82	70	72
8	35	F	335	320	86	74	76
9	37	M	355	335	90	77	79
10	39	F	380	348	95	80	81
11	40	M	405	350	98	82	83
Type 2 (n=3)							
12	22	F	200	185	50	40	41
13	26	M	250	240	65	52	53
14	34	F	325	310	84	72	74
Type 3 (n=3)							
15	28	M	270	260	70	58	60
16	32	F	300	290	80	66	68
17	36	M	345	330	88	76	78

Table 2 shows the progressive increase in the mean diameter of the caval opening (CO) and foramen venae hepaticae (FVH) with advancing gestational age in all 17 fetuses. In Type 1 (n=11), a single FVH was present and both CO and FVH enlarged steadily from 2 mm and 1.5 mm at 21 weeks to 7 mm and 6.5 mm at 40 weeks respectively. In Type 2 (n=3), two hepatic venous foramina were observed, with CO ranging from 2.5–5.5 mm and FVH values

increasing proportionally with age. In Type 3 (n=3), three hepatic venous foramina were present, showing larger measurements overall, where CO increased from 4–6 mm and FVH diameters also progressively enlarged. Overall, the findings indicate a positive correlation between fetal age and enlargement of diaphragmatic venous openings, with greater number of hepatic foramina associated with comparatively larger dimensions.

Case No.	Age* (week)	Sex	CO (mm)	FVH 1 (mm)	FVH 2 (mm)	FVH 3 (mm)
Type 1 (n=11)						
1	21	M	2	1.5	–	–
2	23	F	2.5	2	–	–
3	25	M	3	2.5	–	–
4	27	F	3.5	3	–	–
5	29	M	4	3.5	–	–
6	31	F	4.5	4	–	–
7	33	M	5	4.5	–	–
8	35	F	5.5	5	–	–
9	37	M	6	5.5	–	–
10	39	F	6.5	6	–	–
11	40	M	7	6.5	–	–
Type 2 (n=3)						
12	22	F	2.5	1.5	1	–
13	26	M	3.5	2.5	2	–
14	34	F	5.5	4.5	3.5	–
Type 3 (n=3)						
15	28	M	4	3	2.5	2
16	32	F	5	4	3.5	3
17	36	M	6	5	4.5	4

Discussion

The current retrospective fetal study had shown that morphometric measurements crown-rump length, head circumference, biparietal diameter, the length of the femur and the length of the foot, all improved proportionately with gestational age (21 to 40 weeks). The results of these findings are in line with the known patterns of fetal biometric growth patterns in the available anatomical and developmental literature, under which linear growth should be observed throughout the second half of gestation. Malas et al. have documented an increase in the size of the diaphragmatic dimensions with further gestation period, which implies structures connected with the caval opening do increase in size in a parallel proportion to the overall size of the fetus (Malas, Evcil, and Desdicioglu, 2007) [10]. The caval opening in our series rose over the 21 weeks to 40 weeks, by an almost equal increment of 2 mm to 7 mm, which is in very close agreement with this age-related growth. Though Malas et al. have not reported hepatic venous foramina values, their gradual enlargement of the diaphragmatic size indicates that the two exterior fetal parameters and the diaphragmatic vascular apertures enlarge at the same rate.”

In our specimens there were one to three hepatic venous openings to inferior vena cava (IVC). According to the classical descriptions, the hepatic veins normally drain into the IVC through three major hepatic veins (right, middle and left) (Borley, 2005) [1]. But the anatomical studies on adults often vary. The authors noted that the middle and the left hepatic veins tend to join to create common trunk to enter the IVC (Wind et al., 1999) [3]. Our type 1 unborn children that showed one foramen venae hepaticae with a consistency between 1.5 mm to 6.5 mm are similar to this mature structure where the venous confluence is before entry. Types 2 and 3 fetuses, on the other hand, had two and three separate foramina each, indicating the retention of independent venous routes as opposed to developing a common trunk in fetuses. This helps prove the hypothesis that adult venous patterns could be due to postnatal remodeling of converting initially multiple fetal channels.

In adults, accessory hepatic veins associated with segment VI and VII stated to drain directly into the IVC (Buhe et al., 2008) [4]. Such accessory vessels can open more venous outlets around the caval groove. The adult accessory drainage pattern is paralleled by our type 3 fetuses which possess three foramina with a diameter of 2 mm to 5 mm. Nevertheless, as opposed to adult cases in which the accessory veins are opened below the diaphragm, our experiment showed them to be opened within the diaphragmatic substance. This disparity implies that as individuals mature the venous entry points could shift downwards with swelling of the liver and the abdomen becoming lower.

The other significant difference is the draining of hepatic veins into the right atria. Adult cases give reports of unusual left hepatic vein drainage either on its own or via the coronary sinus (Azuma et al., 2002; Yoshinaga and Kodama, 1997) [7,8]. These reports explain the aberration by the existence of the remnants of the embryonic venous channels on the left side sinus horn and the ductus venosus. In our fetuses, all the hepatic veins never opened above the diaphragm or emptied directly into the atrium; rather they emptied into the IVC inside the diaphragm. Thus, anomaly in adults could be considered as retention of an embryonic process that changes inferiorly once a child is born. The baby shape that we have seen could therefore be a stage in development and not a deformity.

The developmental implication was also reflected on the location of accessory foramina. Other studies done on adults had reported openings on both sides of the caval opening (Wind et al., 1999; Azuma et al., 2002) [3,7]. In our type 1 type of fetuses, we found the foramina located mostly at the right side of the caval pore, and in type 2 and type 3, we found them at both sides. This symmetrically distributed fetal life can later become the asymmetrical life of the adult. This type of remodeling would be caused by differentiations in the growth of the hepatic lobes as well as the rotation of the caval groove after birth.

As far as dimensional relations are concerned, adult radicaliologic and surgical literature underlines hepatic venous caliber is related to hepatic blood flow and segmental drainage (Sahani et al., 2004) [11]. We have shown a steady enlargement of the diameter of single hepatic foramina during the course of gestation, with a range of 1225 mm 1237 mm at the beginning of gestation and 46.5 mm 56.7 mm at the end of gestation, indicating that there was a gradual expansion of hepatic venous return with the development of portal circulation. Surprisingly, the diameter of the cav opening increased steadily with age but the diameter of the separate foramina was different according to the number of them. The single opening was greatest in type 1 fetuses as compared to type 3 fetuses with several openings. This negative correlation suggests a redistribution of the venous flow and not a linear increase in the size of the diaphragm, which is in contrast with the linear increase in the size of the diaphragm as described by Malas et al. (2007) [10].

Our cases also lack any age clustering, which makes them similar to adult anatomy where the patterns of the hepatic veins are independent of sex and body size (Bergman et al, 2009) [2]. Our sample was almost balanced in gender and morphological range was compatible throughout the gestational ages, which confirms the idea that venous structure is set during embryogenesis and not during late gestational development.

Hepatic surgery and liver transplantation clinically need an accurate knowledge of the venous drainage patterns. To avoid congestion, adult surgical research focuses on the reconstruction of the accessory hepatic veins (Fan and Wong, 2008; Sahani et al., 2004) [5,11]. According to our fetal observations, these channels of accessory appear as individual diaphragmatic openings, and subsequently merge or revert. Thus, the postnatal vascular anatomy may be predicted by prenatal identification of abnormal venous channels on obstetric ultrasound.

In summary, the progressive increase in the diameter of the caval pore and hepatic foramina in our fetuses conform to developmental enlargement of the diaphragm, whereas the venous openings are comparable to adult anatomic variability. Nevertheless, the fetal veins open in the diaphragm into the IVC, contrary to the adult cases when hepatic veins drain just above the diaphragm, which is indicative of transitional developmental stage. These findings imply that the variations of the adult hepatic venous system tend to be a developmental holdover of more than one fetal diaphragmatic venous channel and not a postnatal defect.

Conclusion

The current retrospective fetal study reveals morphological variability in hepatic venous drainage to the inferior vena cava in the diaphragmatic area with the most common pattern of a single hepatic venous opening and less common patterns of multiple accessory openings. The complexity of venous entry increases with advancing gestational maturity, indicating progressive differentiation and remodeling of the hepatic venous system rather than random variation. These findings suggest that the arrangement of hepatic veins at the caval opening is developmentally regulated and may represent transitional stages toward the postnatal anatomy. Recognition of these patterns is important for understanding normal fetal vascular morphogenesis and for anticipating anatomical variations relevant to fetal imaging, pediatric surgery, and hepatic or diaphragmatic interventions.

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