

Three-dimensional anatomical characterization of the first jejunal trunk and its relative venous contribution

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Abstract

Background: The anatomical relationship between the superior mesenteric artery (SMA) and first jejunal trunk (FJT) is important for understanding the anatomy around the mesopancreas during pancreaticoduodenectomy (PD). However, detailed three-dimensional (3D) anatomical characterization of the FJT and its relative venous contribution remains limited.

Methods: Imaging parameters evaluated using 3D computed tomography (CT) were compared between the Dorsal and Ventral types, classified according to the relationship between the FJT and SMA. The anatomical features and venous confluence patterns were evaluated. The relative venous contribution of the FJT was assessed using the D ratio, defined as the diameter ratio between the FJT and main portal vein.

Results: Among 114 patients, 77 (67.5%) had the Dorsal type and 37 (32.5%) had the Ventral type. Venous confluence patterns differed significantly between them ($P < 0.001$). The Ventral type showed a more cranial inflow into the superior mesenteric vein than the Dorsal type ($P < 0.0001$). The relative venous contribution of the FJT was significantly higher in the Ventral type than in the Dorsal type ($P < 0.003$), with the D ratio reflecting the relative size of the FJT in the mesenteric venous system.

Conclusions: 3D-CT demonstrates that Ventral type of FJT have distinct imaging features, including more cranial venous confluence patterns and greater relative venous contribution within the mesenteric venous system. Assessment of the FJT-SMA relationship on preoperative CT may improve anatomical recognition before PD, particularly in patients with ventral-type anatomy.

1. Introduction

The mesopancreas has received increasing attention in the field of pancreatic surgery. The mesopancreas is a concept proposed by Gockel et al. in 2007 and is defined as the neural and lymphoid tissue between the dorsal pancreatic head and the superior mesenteric artery [1]. It includes the plexus of pancreatic head II, lymph nodes around the superior mesenteric artery (SMA), and the inferior pancreaticoduodenal artery (IPDA). Among these, the IPDA has been reported as a recognizable landmark for complete resection of the Mesopancreas [2]. However, the IPDA is surrounded by complex fibrous tissues (nerve and fibrous tissues, NFTs), making it difficult to recognize before dissection around the SMA [1]. Therefore, to approach the mesopancreas, it is necessary to recognize surrounding tissues other than the IPDA as landmarks, and various approaches have been developed for this concept [3].

The present study investigated the anatomical relationship between the SMA and the first jejunal trunk (FJT) to understand the anatomy around the mesopancreas, focusing on its anatomical characteristics. Although many reports have discussed the arterial branches from the SMA, few have described the proximal jejunal veins in detail, especially the FJT converging variations [4–11]. Furthermore, few studies have discussed a rare complication of extensive jejunal congestion after sacrificing the FJT based on detailed anatomical characteristics of the FJT [4, 9].

The aim of the present study was to describe the vascular characteristics of the FJT from various perspectives. Precise anatomical knowledge of the FJT can help surgeons recognize surgical pitfalls during pancreaticoduodenectomy (PD) [12, 13], especially in the Ventral type of the FJT, which runs in front of the SMA.

2. Methods

2.1 Patients

The medical database of Otsu Red Cross Hospital during from 2018 to 2022 was examined retrospectively. A total of 146 PDs were performed for various diseases at our hospital between January 2018 and December 2022. Of these, 114 cases were included in this analysis, excluding 26 cases with portal vein circular resection, three cases of completion pancreatectomy on the pancreatic head side, two cases with portal vein compression by tumor, and one case of missing imaging data.

2.2 Anatomical relationship between the SMA and FJT

The anatomical relationship between the SMA and FJT was classified into two groups. The FJT running dorsal to the SMA was defined as Dorsal type, and the FJT running ventral to the SMA was defined as Ventral type. In this study, we analyzed the anatomical differences between these two groups.

2.3 Three-dimensional CT evaluation

Multidetector-row computed tomography (CT) was performed using an 80-row CT system (Aquilion PRIME; Canon Medical Systems, Tokyo, Japan). The routine method for pancreatic dynamic examination at our institution was as follows: acquisition parameters: tube voltage, 120 kVp; helical pitch, 65.0; and reconstruction thickness, 1.0 mm. Nonionic iodinated contrast material, iopromide, was infused at 600 mgI/kg of body weight. Iomeprol was administered when the body weight was > 78 kg. The bolus tracking technique (Real Prep; Canon Medical Systems) was used to acquire arterial phase scanning data. The region of interest was placed in the abdominal aorta at the same level as the hepatic hilar area, and the trigger threshold level was set to a CT value of 150 HU with a 20 s delay. Portal phase scanning was initiated 60 s after the injection of contrast media.

Preoperative CT images were evaluated using three-dimensional (3D) CT reconstruction software (SYNAPSE VINCENT FUJIFILM, Tokyo, Japan). Arterial reconstruction was performed based on the arterial phase scanning data. Portal and pancreatic reconstructions were based on portal phase scanning data. These reconstructed data were combined to create 3D anatomically reconstructed images around the pancreas. All 3D images were obtained for each patient by a pancreaticobiliary surgeon.

The jejunal arteries were detected in their branching order: the first jejunal artery (J1A), second jejunal artery (J2A), and so on. Although there is no consensus on the definition of jejunal veins, they are detected with their accompanying jejunal arteries: the first jejunal vein (J1V) with J1A, the second jejunal

vein (J2V) with J2A, and so on. Several jejunal veins generally join to form a jejunal venous trunk and flow into the superior mesenteric vein (SMV). The FJT was defined as the first-order trunk draining into the SMV, and the second jejunal venous trunk (SJT) was defined in the same manner [14].

During CT evaluations, the inferior mesenteric vein (IMV), middle colic vein (MCV), and gastrocolic trunk (GCT) were observed to identify their drainage routes into the SMV. Several values were measured to analyze the anatomical characteristics around the FJT according to the measurement function installed in the CT viewer system. All the following parameters were measured in the axial views of 1.0 mm CT images. The diameters of the portal vein (PV) and FJT (Dp and Df) were measured as parameters of drainage flow, and the lengths from the splenic vein (SpV) to the FJT and SJT (L1 and L2) were measured as parameters of the confluence position with the SMV. Dp was defined as the diameter of the PV, just cranial to the confluence of the SpV and SMV. Df was defined as the diameter of the FJT at the confluence of the FJT and SMV. L1 was calculated by subtracting the count between the CT slices where Dp and Df were measured. L2 was calculated in the same manner as L1 (Fig. 1). All these parameters were initially collected by one certain person among the authors and were assessed by two other authors to confirm their validity and reproducibility.

2.4 FJT drainage index definition

Using the values measured above, the following index was adapted to represent the drainage volume carried by the FJT (Fig. 1):

$$D \text{ ratio} = (\text{Diameter of FJT})/(\text{Diameter of PV}) = Df/Dp$$

According to Ohm's law, blood flow is inversely proportional to vascular resistance since the portal pressure is constant in each individual. Vascular resistance is inversely proportional to vascular diameter; hence, blood flow is proportional to vascular diameter. We defined the D ratio as the FJT diameter divided by the PV diameter, which becomes an indicator of FJT blood flow when comparing individuals. Therefore, a large value indicates a large drainage volume through the FJT.

2.5 FJT drainage territory

The jejunal venous trunks are responsible for venous drainage from the proximal jejunal loops, and the definition of their drainage territory differs according to the literature, that is, whether to define the drainage territory as the area through which the jejunal arteries perfuse [8] or the area through which the jejunal veins flow [9]. The former approach was adopted in this study. For example, if the FJT flows in the regions of J1A, J2A, and J3A, its drainage territory is called the J1 + 2+3A area.

2.6 Statistical analysis

The data and values shown in the tables are medians (ranges or percentages) or ratios. Univariate analyses were performed using the χ^2 test (for categorical variables) and Student's t-test (for continuous

variables in two groups). In all analyses, statistical significance was defined as $P < 0.05$ (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$).

3. Results

3.1 Patients' characteristics (Table 1, Fig. 2)

The preoperative patient characteristics are listed in **Table 1**. Among the 114 patients, 77 (67.5%) had Dorsal type, and 37 (32.5%) had Ventral type. The background diseases included 77 malignant tumors (46 pancreatic cancers, 24 biliary tract cancers, and seven duodenal cancers) and 37 benign tumors. Furthermore, when the SJT position was also taken into consideration in addition to the FJT position, the group with dorsal FJT and dorsal SJT was the most common, with 62 (54.4%) cases, while the group with ventral FJT and ventral SJT was the least common, with eight (7.0%) cases (Fig. 2).

3.2 Confluence of the FJT with IMV or MCV (Fig. 3a)

Whether the FJT merged with the drainage routes of the IMV and MCV was also analyzed. In the Dorsal type, there were no cases of IMV or MCV merging with the FJT (0%). In contrast, in the Ventral type, there were 19 cases of MCV or IMV merging with the FJT, accounting for more than half of the Ventral type (51.4%). Therefore, a significant difference existed between the two types regarding the confluence of the FJT with the IMV or MCV ($P < 0.001$).

3.3 Positional relationship between the FJT and GCT (Fig. 3b)

The positional relationship between the FJT and GCT flowing into the SMV was also analyzed. In the Dorsal type, the FJT entered the SMV more caudally than the GCT in 71 (92.2%) cases. In contrast, in the Ventral type, the FJT entered the SMV at the same level as or cranial to the GCT in 31 (83.8%) cases, accounting for the majority of the group ($P < 0.001$).

3.4 Lengths from the SpV to FJT and SJT (Table 2)

The position of the FJT flowing into the SMV was analyzed by measuring the distance from the SpV (L1) (**Table 2A**). The FJT was further divided into two subgroups: one that only gathered the jejunal veins and the other that collected drainage from the IMV or MCV, respectively. Overall, the Ventral type had a significantly lower L1 than the Dorsal type ($P < 0.0001$), flowing more cranially into the SMV. A similar relationship was observed in the subgroup that only gathered jejunal veins ($P < 0.0001$). Another subgroup that also collected drainage from the IMV or MCV existed only in the Ventral type and had much lower L1. This result revealed that the latter subgroup merged more cranially with the SMV.

The distance between the FJT and SJT (L2-L1) was also evaluated and similarly sub-grouped according to the presence or absence of IMV and/or MCV convergence (**Table 2B**). The Ventral type had a

significantly longer L2-L1 than the Dorsal type ($P < 0.001$). However, when considering only the jejunal vein aggregation subgroup, there was no difference in L2-L1 between the dorsal and ventral types. L1 tended to be much lower in the IMV/MCV incorporated subgroup of the Ventral type, as mentioned above. Hence, this difference explains the longer L2-L1 in the Ventral type than in the Dorsal type when analyzed without subclassification.

3.5 FJT drainage territory and D ratio (Table 3, Online Resource 1)

The relationship between the FJT drainage territory and D ratio was analyzed according to the subgroups defined in the previous results (**Table 3**). In both the Dorsal and Ventral types, the D ratio showed a stepwise increase as the arterial perfusion territory associated with the FJT expanded. The D ratio was also higher in cases with the addition of IMV and MCV drainage.

Overall, the D ratio was significantly higher in the Ventral type than in the Dorsal type ($P = 0.003$). A similar relationship was also observed even in the subgroup that only gathered jejunal veins ($P = 0.04$).

The relationship between the FJT drainage territory and its absolute diameter was also analyzed (**Online Resource 1**). The FJT diameter showed no significant difference between the Dorsal and Ventral types. Accordingly, the FJT diameter alone did not consistently correspond to differences in the drainage territory, whereas the D ratio reflected relative differences within the mesenteric venous system.

4. Discussion

4.1 Anatomical relationship between the SMA and FJT

Most pancreatic surgeons know that preoperative CT evaluation is very important for safely performing complicated procedures involving the mesopancreas. Many previous reports have discussed anatomical characteristics around SMA and SMV [6, 11, 14, 15]. However, few have described the proximal jejunal veins in detail, especially the FJT converging variations [4–11]. Without preoperative information about the FJT, it can be misidentified as another vein and dissected unintentionally. In this context, the present study focused on systematically characterizing the anatomical features of the FJT based on its positional relationship with the SMA.

First, we examined the frequencies of the Dorsal and Ventral types. **Result 3.1** showed the Dorsal type accounted for 67.5%, while the Ventral type accounted for 32.5%, consistent with the range reported in previous studies [4, 6, 7, 9, 10]. These findings confirm that the Dorsal type represents a more common anatomical setting.

Next, we examined the positional relationship between FJT and IMV, MCV, or GCT. In **Result 3.2, 3.3, and 3.4**, it was found that the Ventral type of FJT tended to form a common trunk with the IMV or MCV, and to flow into the SMV at a more cranial position than the GCT. Therefore, the Ventral type of FJT was likely to

converge or penetrate across several mesenteries (meso-jejunum and meso-colon). These mesenteries tended to merge with the upper mesenteries (meso-gastrium and meso-duodenum) more cranially, making the fused layer more complex. Such anatomical complexity may complicate anatomical orientation during PD in the Ventral type of FJT, underscoring the importance of careful preoperative anatomical assessment.

Finally, we analyzed the drainage territory of the FJT and the imaging-based D ratio. In **Result 3.5**, it was shown that the D ratio tended to increase as jejunal drainage increased, and as venous drainage via the MCV and IMV was additionally involved. Although the D ratio differed between the Dorsal and Ventral types, this parameter should be interpreted as reflecting relative venous contribution rather than absolute drainage capacity. Notably, the absolute diameter of the FJT itself did not consistently correspond to differences in drainage territory, consistent with previous reports that focused primarily on vessel diameter [4, 7, 9]. Together, these findings highlight the anatomical variability of the FJT and support the use of positional classification to facilitate preoperative anatomical understanding of the FJT.

In summary, the Ventral type of FJT exhibits distinct anatomical features compared with the Dorsal type, particularly with respect to venous confluence patterns, relative venous contribution, and spatial relationships within the mesentery. Recognition of these variations may assist in anatomical orientation during PD.

4.2 Embryology

The embryonic development of mesenteric vessels [16–20] provides a possible anatomical framework for understanding the positional relationship between the SMA and the FJT [4–11].

The mesenteric artery and vein arise from the vitelline artery (VA) and vein (VV) during the 4th–5th weeks of development. The centrally located VA forms the basis of the superior mesenteric artery (SMA), whereas the left VV persists as the superior mesenteric vein (SMV) following the regression of the right VV [19, 20] (Fig. 4a). Between the 6th and 10th weeks, the midgut undergoes counterclockwise rotation around the SMA [16–18], and the mesenteric structures reorganize into a single mesentery (Fig. 4bcd).

Within this developmental context, the Dorsal type of FJT appears consistent with the typical anatomical arrangement of the SMA and SMV. In contrast, the Ventral type may reflect individual variations in mesenteric fusion or venous remodeling during development. These embryological considerations are presented as a conceptual background for understanding the anatomical variability observed in our analysis.

4.3 Surgical application

The present study demonstrated that the Ventral type of FJT differs anatomically from the Dorsal type with respect to venous confluence patterns, relative venous contribution and spatial relationships within

the mesentery. These differences highlight the importance of preoperative recognition of the SMA/FJT anatomy before PD, particularly to avoid venous misidentification or unexpected bleeding.

Although there have been reports that dissection of the Ventral type of FJT can cause congestion of the anastomosed jejunum during PD [4, 9], it is a rare complication, and no cases of jejunal congestion during PD were observed among the analyzed 114 cases. Importantly, inadvertent division of the FJT may result in venous congestion during PD, also underscoring the value of preoperative CT-based anatomical recognition.

The imaging-based D ratio was introduced as a parameter to describe the relative venous contribution of the FJT within the mesenteric venous system. As it reflects relative anatomical characteristics rather than absolute functional drainage, the D ratio should be interpreted as supplementary information to enhance anatomical understanding. We propose that the decision to sacrifice the Ventral type of FJT should be made carefully during actual PD. In the Ventral type, the D ratio may serve as a reference for its relative venous contribution and intraoperative FJT clamping may be considered before dissection.

The impact of FJT variations on surgical outcomes remains unclear. Previous studies have reported no significant differences in morbidity or mortality between patients with and without FJT resection [5, 9, 21]. However, some authors have suggested possible associations with transfusion risk [22] or oncologic outcomes [23]. These findings indicate that further investigation is needed.

In summary, classification of the SMA–FJT relationship into Dorsal and Ventral types provides a framework for understanding anatomical variability. Attention to these variations, particularly in the Ventral type, may assist preoperative anatomical recognition and surgical orientation during PD.

4.4 Limitations

This study had some limitations. The main limitations include the retrospective nature of the analysis and the enrollment of patients in a single institution. Another limitation is that there was no analysis on whether preservation of the Ventral type of FJT had any impact on surgical outcomes. No outcome-based thresholds for the D ratio have been established. Future studies incorporating larger cohorts and functional validation are necessary to further clarify the clinical significance of FJT.

Statements and Declarations

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Author Contributions

R Ataka: Project development, Data collection, Data analysis, Manuscript writing. Y Nakayama: Data collection, Data analysis, Manuscript writing. K Kitaguchi: Data collection. Y Ikeno: Data collection. E

Toyoda: Manuscript editing. T Hirose: Manuscript editing.

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Data Availability

The datasets generated and analyzed during the current study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author on reasonable request.

Consent to Publish

Not applicable. The manuscript does not contain identifiable personal data.

Ethics and Consent to Participate

This study was approved by the Institutional Review Board (#528: OTSU pancreas study) on the basis of the Ethical Guidelines for Clinical Research of the Ministry of Health, Labor and Welfare in Japan and conformed to the Declaration of Helsinki. The requirement for written informed consent was waived by the ethics committee due to the retrospective nature of the study and the use of anonymized clinical data.

Competing Interest

The authors declare no conflicts of interest regarding the publication of this study.

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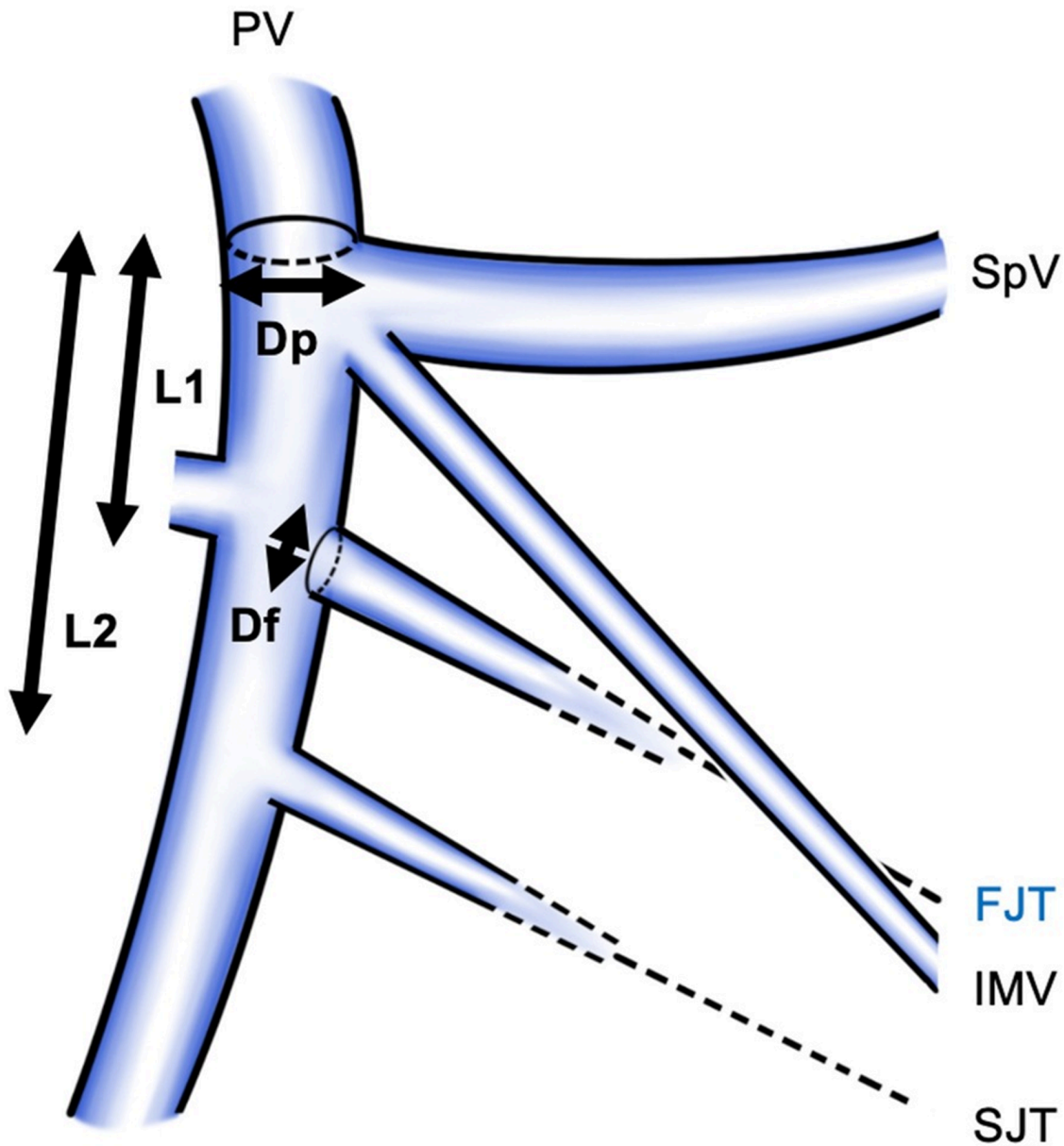
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Tables

Tables 1 to 3 are available in the supplementary files section

Figures



D ratio

$$= (\text{Diameter of FJT}) / (\text{Diameter of PV})$$

$$= D_f / D_p$$

Figure 1

Imaging parameters in the portal system: Dp, diameter of the PV; Df, diameter of the FJT; L1, distance from the SpV to the FJT; L2, distance from the SpV to the SGT. The D ratio is defined as the value calculated by dividing Df by Dp. Abbreviations: PV, portal vein; SpV, splenic vein; FJT, first jejunal trunk; SGT, second jejunal trunk; IMV, inferior mesenteric vein.

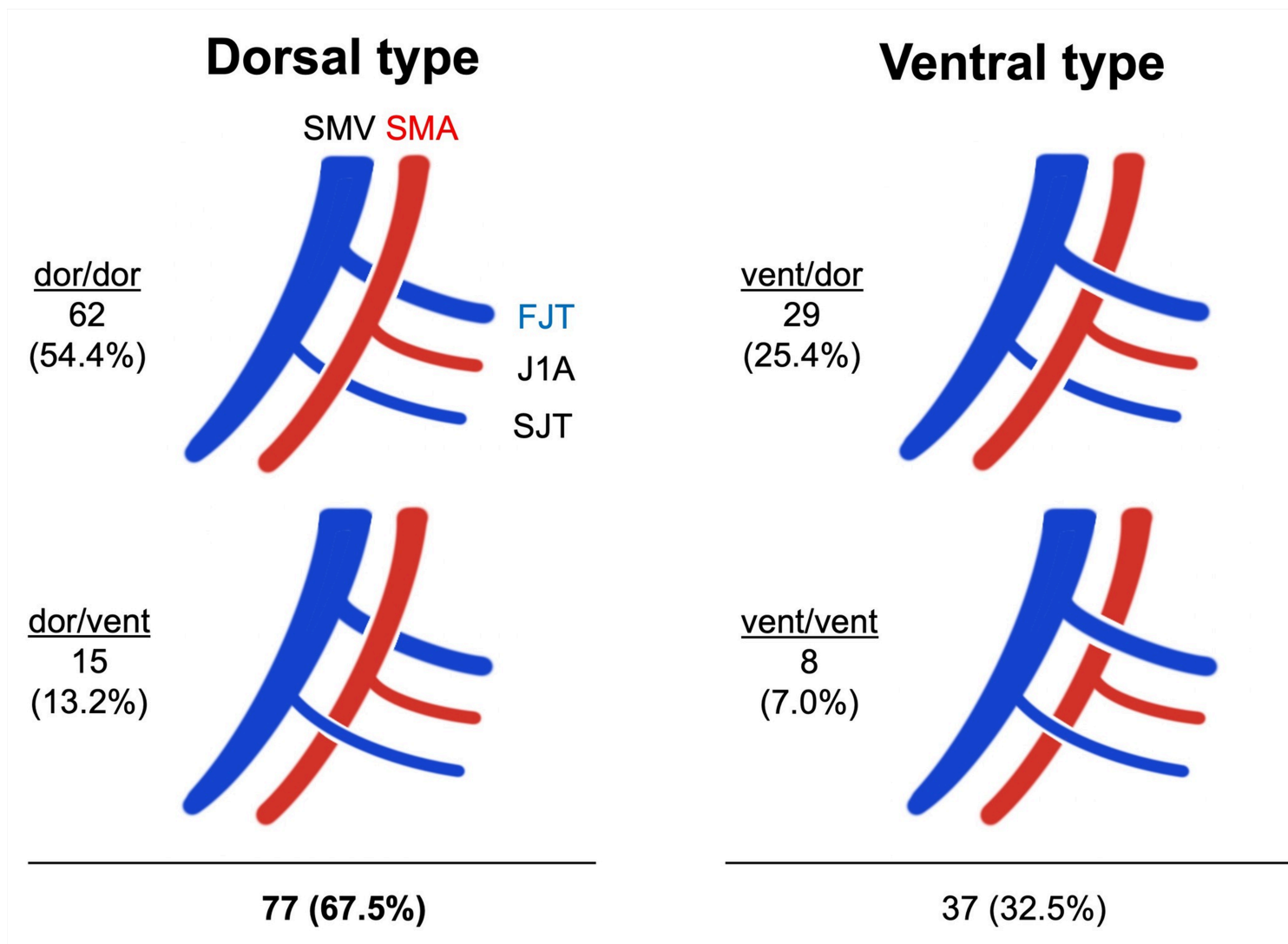


Figure 2

Proportion of the Dorsal and Ventral types, considering both the FJT and SJT positions. Abbreviations: SMA, superior mesenteric artery; SMV, superior mesenteric vein; FJT, first jejunal trunk; SJT, second jejunal trunk; J1A, first jejunal artery.

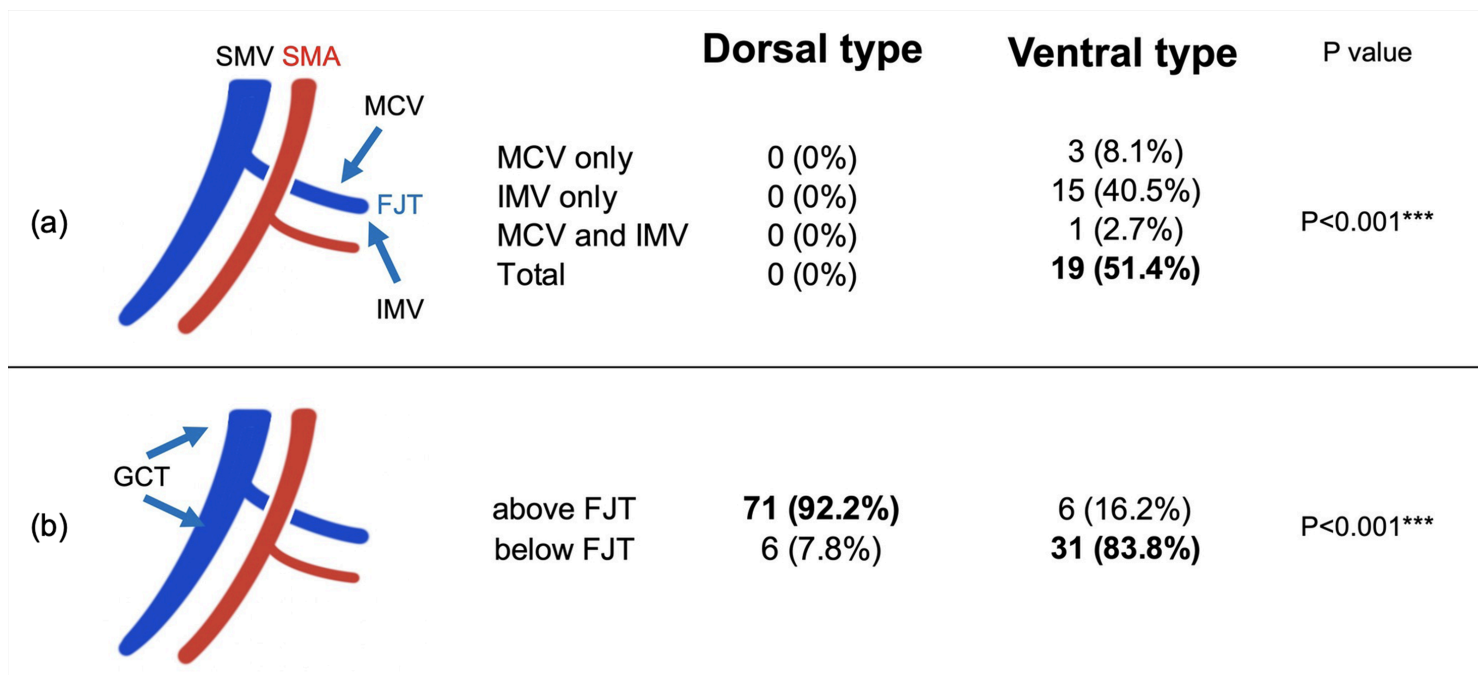


Figure 3

(a) Characteristics of the Dorsal and Ventral types with regard to the confluence of the FJT with the IMV or MCV, and (b) positional relationship between the FJT and GCT flowing into the SMV. Abbreviations: SMA, superior mesenteric artery; SMV, superior mesenteric vein; FJT, first jejunal trunk; IMV, inferior mesenteric vein; MCV, middle colic vein; GCT, gastocolic trunk.

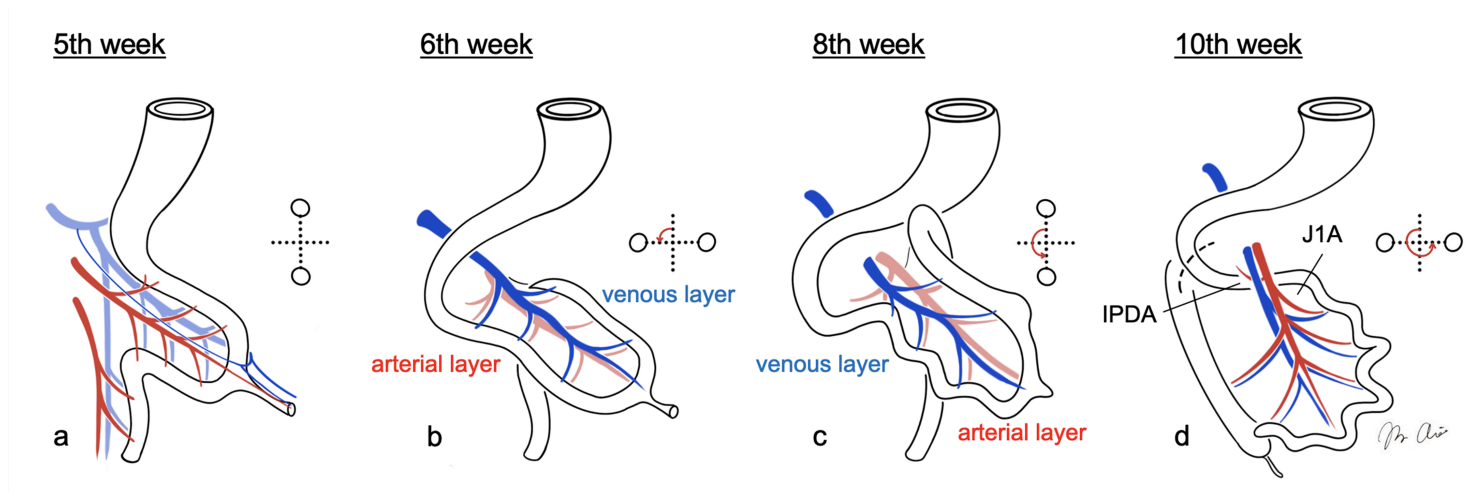


Figure 4

(a, b, c, d) Schematic illustration of the mesenteric artery and vein during midgut rotation based on previous reports. A layered vascular structure (arterial and venous layers) is maintained throughout this developmental period. Abbreviations: IPDA, inferior pancreaticoduodenal artery; J1A, first jejunal artery.

Supplementary Files

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