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ORIGINAL CONTRIBUTION

Jejunal Lymphatic and Vascular Anatomy Defines Surgical Principles for Treatment of Jejunal Tumors

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BACKGROUND: The jejunum has a wide lymphatic drainage field, making radical surgery difficult.

OBJECTIVE: Extrapolate results from 2 methodologies to define jejunal artery lymphatic clearances and lymphovascular bundle shapes for radical bowel-sparing surgery.

DESIGN: Two cohort studies.

SETTINGS: The first data set comprised dissections of cadavers at the University of Geneva. The second data set incorporated preoperative 3-dimensional CT vascular reconstructions of patients included in the "Surgery with Extended (D3) Mesenterectomy for Small Bowel Tumors" clinical trial.

PATIENTS: Eight cadavers were dissected. The 3-dimensional CT data set included 101 patients.

MAIN OUTCOME MEASURES: Lymph vessels ran parallel and interlaced with jejunal arteries. Lymphatic clearance was minimal at the jejunal artery's origin, radially spreading thereafter. Jejunal arteries were categorized into 3 groups based on position to the middle colic artery origin on 3-dimensional CT: group A: jejunal artery origins lie cranially and caudally to the middle colic artery; group B: jejunal artery origins lie caudal to the middle colic artery; and group C: jejunal artery origins lie cranial to the middle colic artery. Jejunal veins were classified into 3 groups based on their trajectories to the superior mesenteric artery (dorsally/ventrally/combined).

RESULTS: Lymph vessel clearances were 1.5 ± 1.0 mm at jejunal artery origins. Group A was present in 81 cases (80.2%), group B in 13 cases (12.9%), and group C in 7 cases (6.9%). Jejunal artery median was 4. Fifty-seven jejunal veins (56.4%) ran dorsally to the superior mesenteric artery, 16 (15.8%) ran ventrally, and 28 (27.8%) had a combined course.

LIMITATIONS: Lymph nodes were not counted during dissection because the main observation was the position of lymph vessels.

CONCLUSIONS: Minimal jejunal artery lymphatic clearance implies ligating tumor-feeding vessels at the origin. The intermingled jejunal artery lymphatics imply lymph node dissection along the proximal and distal vessels to the level of the first arcade. Classifying jejunal arteries and veins could simplify the anatomy for surgeons. See **Video Abstract.**

CLINICAL TRIAL REGISTRATION NUMBER: NCT05670574.

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LA ANATOMÍA LINFÁTICA Y VASCULAR DEL YEYUNO DEFINE LOS PRINCIPIOS QUIRÚRGICOS PARA EL TRATAMIENTO DE LOS TUMORES DEL YEYUNO

ANTECEDENTES: El yeyuno tiene un amplio campo de drenaje linfático, lo que dificulta la cirugía radical.

OBJETIVO: Extrapolar los resultados de dos metodologías para definir los aclaramientos linfáticos de la arteria yeyunal y las formas de los haces linfovasculares para la cirugía radical de conservación intestinal.

DISEÑO: Dos estudios de cohorte.

ESCENARIO: El primer conjunto de datos comprendía disecciones de cadáveres en la Universidad de Ginebra. El segundo conjunto de datos incorporaba reconstrucciones vasculares preoperatorias por TC 3D de pacientes incluidos en el ensayo clínico "Cirugía con mesenterectomía extendida (D3) para tumores del intestino delgado".

PACIENTES: Se disecaron ocho cadáveres. El conjunto de datos de TC 3D incluía 101 pacientes.

PRINCIPALES MEDIDAS DE VALORACIÓN: Los vasos linfáticos discurrían paralelos y se entrelazaban con las arterias yeyunales. El aclaramiento linfático era mínimo en el origen de la arteria yeyunal, extendiéndose radialmente a partir de allí. Las arterias yeyunales se clasificaron en tres grupos según su posición respecto del origen de la arteria cólica media en la TC tridimensional. Grupo A: los orígenes de la arteria yeyunal se encuentran craneal y caudalmente respecto de la arteria cólica media; Grupo B: los orígenes de la arteria yeyunal se encuentran caudalmente respecto de la arteria cólica media; Grupo C: los orígenes de la arteria yeyunal se encuentran cranealmente respecto de la arteria cólica media. Las venas yeyunales se clasificaron en tres grupos según sus trayectorias hacia la arteria mesentérica superior (dorsal/ventral/combinada).

RESULTADOS: Los espacios libres de los vasos linfáticos fueron de 1,5+1,0 mm en los orígenes de la arteria yeyunal. El grupo A estuvo presente en 81 (80,2 %), el grupo B en 13 (12,9 %), el grupo C en 7 (6,9 %) casos. La arteria yeyunal tenía una mediana de 4. Un 57 (56,4 %) de las venas yeyunales discurrían dorsalmente a la arteria mesentérica superior, 16 (15,8 %) discurrían ventralmente y 28 (27,8 %) tenían un trayecto combinado.

LIMITACIONES: No se contaron los ganglios linfáticos durante la disección porque la observación principal era la posición de los vasos linfáticos.

CONCLUSIÓN: La mínima limpieza linfática de la arteria yeyunal implica la ligadura de los vasos que alimentan el tumor en el origen. Los vasos linfáticos de la arteria yeyunal entremezclados implican la disección de los ganglios linfáticos a lo largo de los vasos proximales y distales hasta el nivel de la primera arcada. La clasificación de las arterias y venas yeyunales podría simplificar la anatomía para los cirujanos. *(Traducción–Ingrid Melo)*

NÚMERO DE ENSAYO CLÍNICO: NCT05670574.

KEY WORDS: Anatomy; D3 volume; Jejunal tumor; Jejunal vessels; Lymphatics; Operative technique.

There are few articles in the literature describing the jejunal lymphatic and vascular anatomy in detail. *Gray's Anatomy* states that the small bowel (SB) is under a wide field of lymphatic drainage, which makes radical surgical resection difficult when attempting vessel preservation. In addition, 4 to 6 jejunal arteries (JAs) have been reported.[1] Skandalakis et al[2] described lymph vessels that follow arteries and veins to the lymph nodes (LNs) in the mesenteric root, stating that the small-bowel lymphatic anatomy decreases the possibility of curative surgery. Lymphatics bypassing LN stations have been reported, introducing the concept of extensive mesentery excision, as previously announced by Hollinshead et al.[3] The main point in the introduction of complete mesocolic excision for the treatment of colon cancer is the removal of complete and uninjured colic artery lymphovascular bundles to prevent the seeding of cancer cells during surgery.[4] These lymphovascular bundles have been previously defined and described.[5]

Guidelines for the treatment of SB malignancies often state that these should be operated in a manner similar to that of the colon. However, the distinction between the SB and the colon is not only in its length but also in the complexity of its vascular and lymphatic anatomy. The recommendation is that the number of harvested LNs should be at least 8, which is unusually low and probably not applicable to all segments of the SB.[6–8] Recent studies highlight the importance of LN dissection in SB neoplasia. Wang et al[9] found that patients with 7 or more harvested LNs had a more accurate tumor staging and a better prognosis. Similarly, Kankava et al[10] postulated that the tumor stage, as well as a number of 10 or more retrieved positive LNs, affected relapse-free survival in 264 cases of SB neuroendocrine neoplasia (HR 2.63; 95% CI, 1.20–5.78; $p = 0.016$). In addition, Thiessen et al[11] concluded that sampling less than 16 LNs is associated with increased mortality in SB adenocarcinoma in 523 cases. Despite this evidence, the optimal number of LNs to be dissected remains uncertain. A recent trial has reported the benefit of extended mesenterectomy for right colon cancer, which has shown improved 5-year survival rates for patients with affected central LNs.[12] Traditional pizza-pie SB resections have not evolved to include complete lymphovascular bundles of tumor-feeding arteries, as stated in the articles earlier. They do, however, offer the advantage of rapid surgery with minimal complications and ease of performance.

To achieve the goal of comparable LN harvest when operating on SB tumors, partitioning of the SB according to the tumor-irrigating arteries seems reasonable. We propose that one of these groups is the jejunum. The jejunum is irrigated through arteries arising from the superior mesenteric artery (SMA) cranially to the origin of the ileocolic artery (ICA), and a jejunal tumor is irrigated by a JA.[13] In addition, jejunal veins (JVs) add complexity to the anatomy due to their position, trajectory, and caliber.

The present study aimed to establish the lymphatic clearance of individual JAs and the shape of the lymphovascular bundles. The second aim was to classify JA origins and JV confluences according to established anatomical landmarks. The third aim was to define a radical but bowel-sparing surgical technique for the modern treatment of jejunal tumors by extrapolating the results derived from these 2 distinct research methodologies.

MATERIALS AND METHODS

Two data sources were used in this study. The first source of data was the anatomical dissection of cadavers donated to the University of Geneva. According to Swiss law, there is no requirement for ethical approval of studies performed on donated bodies.[14] The second source was CT data sets and 3-dimensional (3D) vascular anatomy reconstructions of patients included in the "Surgery With Extended Mesenterectomy for Small Bowel Tumors" ongoing clinical trial. The trial was approved by the Regional Ethical Committee South-East, Norway (No. 19898), and registered on ClinicalTrials.gov (https://classic.clinicaltrials.gov/ct2/show/NCT05670574). The inclusion criteria were age 18 years or older, signed consent forms, radiologically or scintigraphically diagnosed SB extraduodenal tumors, and well-tolerated general anesthesia. The trial requires that all patients have the vascular anatomy of the region reconstructed in 3D from the preoperative staging CT data set.

Data Collection

Anatomical dissection of the root of the mesentery. This study included 8 embalmed human bodies obtained from the body donor program of the Anatomy Sector, Faculty of Medicine, University of Geneva, Switzerland. The use of human cadaveric material was performed according to the Federal Act on Research Involving Human Beings (Human Research Act), the Guidelines of the Swiss Academy of Medical Sciences, and the principles of the Swiss Society of Anatomy, Histology, and Embryology.[14–16] Donors officially agreed to the use of the whole body or body parts for research purposes by signing the body donation statement form.[17] The exclusion criteria for this study were digestive tract diseases and/or surgery. The bodies were injected with Jores solution (formaldehyde, chloral hydrate, Carlsbad salt, and distilled water) and stored in a refrigerator at 4°C. After conditioning to ambient temperature, minute dissection was performed with access to the infracolic compartment of the peritoneal cavity. The transverse colon was pulled cranially, and the SB mesentery spread out from the duodenojejunal junction onward. The anterior-right leaf of the mesentery was carefully removed from a wider area over the SMA/superior mesenteric vein (SMV) using the ICA and middle colic artery (MCA) folds as landmarks. Subserosal fatty tissue was removed by gentle scraping using narrow spatulas, microdissection scissors, small tweezers, and curved forceps. The next step was to follow the arborization of the SMA branches and branches of the SMV affluents, preserving the accompanying lymph vessels, their network, and LNs. This procedure required the use of a 5x magnifying glass with a fluorescent ring lamp. The course of the lymph vessels was followed, and they were separated from the underlying nerve plexuses and connective tissue without disturbing their native anatomical position (see Supplemental Digital Content 1 video *Anatomical Dissection of the Root of Mesentery* at https://links.lww.com/DCR/C507). Throughout the dissection, the working field was regularly sprayed with a phenol solution to preserve the original consistency. Syntopy of the anatomical entities in the area was carefully observed and noted. The following measures were taken with the aid of the digital Vernier electronic caliper (S Cal Work 150 mm, Sylvac, Crissier, Switzerland):

- External diameters of the JAs, MCA, and ICA.
- MCA-ICA distance (intercolic interval).
- Distance between each JA and its accompanying lower-caudal lymph vessel.

Preoperative CT reconstruction. All patients included in the trial underwent a standard preoperative investigation for SB tumors following Norwegian guidelines. These included abdominal and pelvic CT scans, which were used for 3D vascular reconstructions, and no new scans were ordered. The CT data set was analyzed using 2D multiplanar reconstruction with maximum intensity projection and a 3D volume-rendering technique using the Food and Drug Administration–approved OSIRIX MD version 14.0 64-bit image-processing application software (Pixmeo, Bernex, Switzerland), Mimics Medical Image Processing Software version 24.0, and 3-matic medical software, version 16.0 (both for Windows 10 Pro x64; Materialise NV, Leuven, Belgium). The identification, caliber (internal diameter), and course of the vascular structures within the root of the mesentery were analyzed according to previously published detailed articles.[18,19]

All measurements were conducted in metric units (millimeters).

Analysis of 3D-reconstructed CT images and written reports. Data were gathered from the 3D-reconstructed images and written reports. These included information on the presence of the ICA, MCA, JAs, and JVs and their mutual relationships. The distances from the ICA origin, MCA origin, and origins of consecutive JA branches were measured. In addition, we noted the number and caliber of JAs and JVs, the level of JA origin, the course of JVs relative to the SMA, and data on inferior mesenteric vein (IMV) drainage. For practical purposes, JAs were counted from the ICA origin cranially, and the most cranial JA and JV were named the superior JA/JV. The jejunal vessels named superior JA and superior JV are always anatomically present.

Grouping JAs and JVs. JAs are defined as arteries arising from the SMA at the level of the origin of the ICA (first artery) cranially onward.[13] The positions of the JAs were described with regard to the MCA because its origin lies at the level of the pancreatic notch. This gave rise to 3 groups:

Group A: JA origins found cranial and caudal to MCA origin.
Group B: JA origins found only caudal to MCA origin.
Group C: JA origins found only cranial to MCA origin.

The JA groups are represented through schemes and 3D-CT vascular reconstructions in Figure 1. MCA origin was defined as high when originating cranially to the Gastrocolic Trunk of Henle and low when its origin was caudal to it. JVs are veins with confluence to the SMV at the level of the ileocolic vein (ICV) confluence and cranial.[10]

JVs were assigned to 3 groups according to their crossing patterns to the SMA:

- JVs crossing SMA only ventrally.
- JVs crossing SMA only dorsally.
- JVs crossing SMA on both sides (combined course).

Statistical Analysis

Data were analyzed through parametric or nonparametric methods. Observed characteristics were expressed as mean, SD, median, and interquartile range (IQR). We used the Kolmogorov-Smirnov test for the assumption of normality. Continuous parametric data were analyzed using the Student *t* test and 1-way ANOVA. The post hoc Bonferroni test calculated the mean differences in the ICA-MCA distance between JA groups. Significance was set at a 2-sided p value of <0.05. IBM SPSS Statistics 21 (Chicago, IL) was used for the analysis.

Ethics Approval

Approved by the Regional Ethical Committee South-East, Norway (No. 19898).

RESULTS

Anatomical Dissection in the Root of the Mesentery

A total of 8 cadavers (4 men) were dissected with a median age of 82 years. The median number of JAs present was 3 (IQR 3). All 8 cases presented with MCA and ICA, and 1 had a right colic artery. As for the JAs, in 5 cases, there was a solitary vessel in the ICA-MCA interval, and in 3 cases, there were multiple JAs in the same

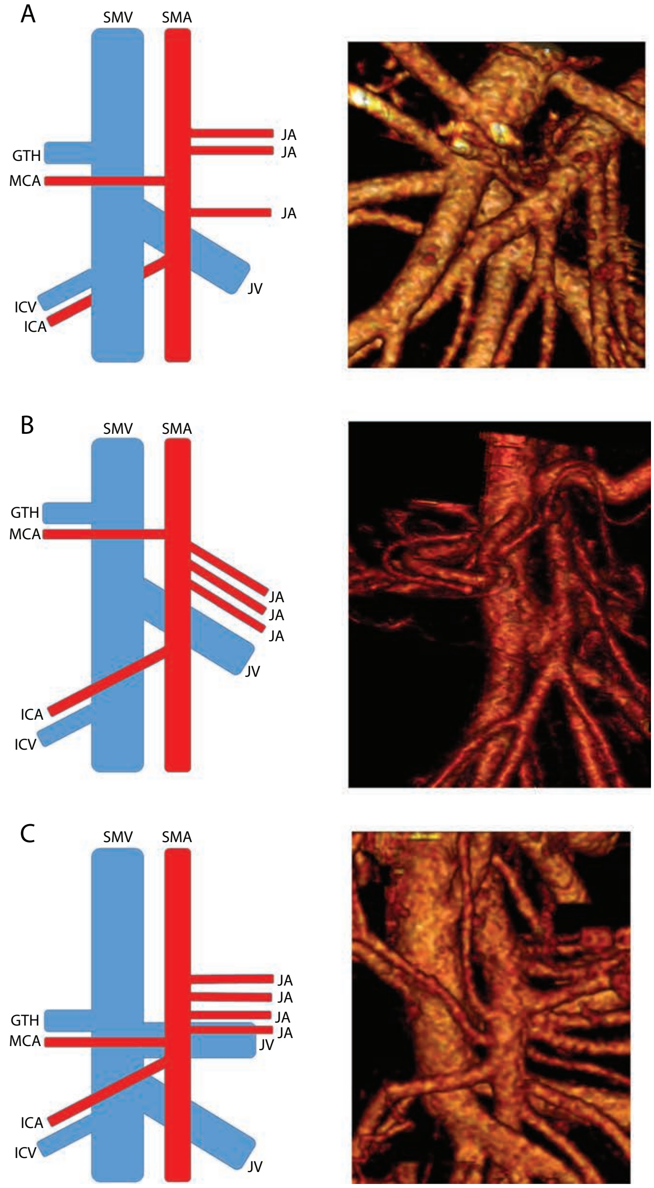

FIGURE 1. Jejunal artery group schematics and their 3D-CT vascular reconstructions. A–C, Groups A, B, and C are illustrated through sketches on the left side, whereas their adequate 3D-CT vascular reconstructions are to the right. 3D = 3-dimensional; GTH = gastrocolic trunk of Henle; ICA = ileocolic artery; ICV = ileocolic vein; JA = jejunal artery (JA2, ie, second jejunal artery); JV = jejunal vein; MCA = middle colic artery; SMA = superior mesenteric artery; SMV= superior mesenteric vein.

interval. Lymphatic drainage of the proximal jejunum was organized in a series of longitudinal vessels parallel to and interlaced with the JAs with numerous mutual anastomoses, resulting in a dense lymphatic mesh (Fig. 2). These vessels radiated centrifugally among the JAs in a fan-like manner with the pivot point at the pancreatic notch and root of the transverse mesocolon. Among other vessels, there was a large collector lymphatic channel that courses immediately along the left border of the SMA, denoting the watershed between the small and large bowel lymph

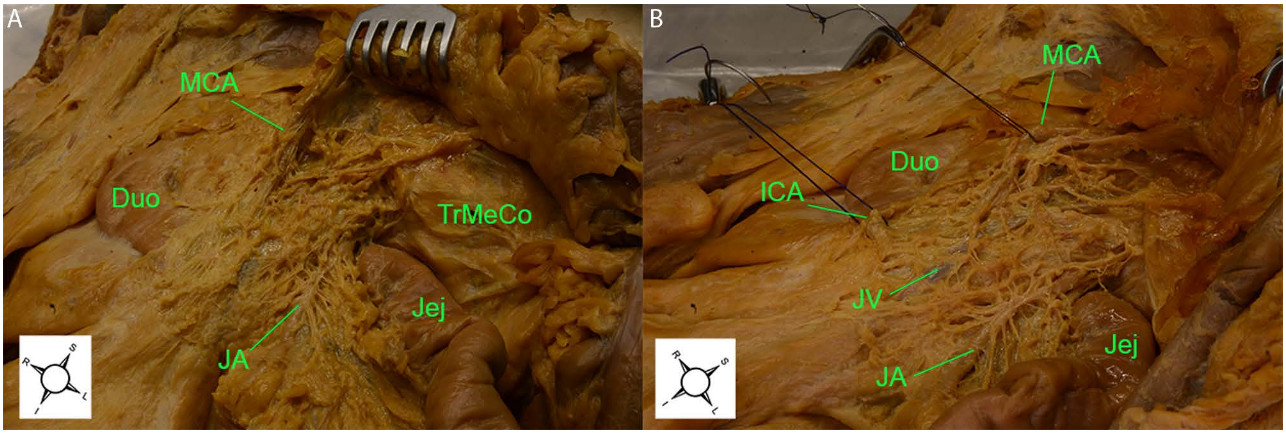

FIGURE 2. Anatomical dissection of the lymph vessels in the root of the mesentery. A, View after removing the peritoneal membrane and subperitoneal adipose and connective tissue and the transverse colon lifted upward. B, MCA and ICA looped with ligature threads. Compass: superior, inferior, right, left. Duo = duodenum; ICA = ileocolic artery; JA = jejunal artery; Jej = proximal jejunum; JV = jejunal vein (crossing SMA anteriorly); MCA = middle colic artery; TrMeCo = transverse mesocolon.

TABLE 1. Measures on individual JAs and their lymphatic clearances on anatomical dissection specimens

Sex	*Age*	*JA caliber X*[a]	*JA caliber Y*[a]	*ICA-MCA*[a]	*MCA caliber*[a]	*ICA caliber*[a]	*LyVe distance*
M	73	7.2	5.55; 7.20	16.95	6.1	7.05	3.1
F	82	5.9	3.85; 4.75	31.25 (ICA-RCA 21.05)	4.45 (ICA-RCA 3.05)	7.40	2
F	90	4.6	5.85	20.3	5.4	5.65	2.1
M	42	5.2; 4.95	None	34.5	4.6	4.90	0.5; 0.2
M	85	4.95	5.75; 4.25; 3.50	29.65	5.3	7.85	0.4
F	78	6.85	5.8	18.05	3.3	4.35	2.60
F	82	4.40; 5.35; 3.60; 2.60; 3.50	None	42.35	4.65	3.10	0.00; 1.10; –; 0.30; 2.05
M	86	5.20; 7.25; 3.55; 5.05	3.2	23.65	5.00	6.20	1.80; 0.30; 0.1; 0.00[b]

F = female; ICA = ileocolic artery; JA = jejunal artery; JA caliber X = the external caliber of JA at their origins (mm), which are caudal to the MCA; if consecutive measures in cells are present, each represents a caliber for separate JA; JA caliber Y = the external caliber of JA s at their origins (mm), which are cranial to the MCA; if consecutive measures in cells are present, each represents a caliber for separate JA; LyVe = lymph vessel; LyVe distance = lymph vessel clearance from the caudal JA in the intercolic interval (ICA-MCA interval/caudal to the MCA); M = male; MCA = middle colic artery; RCA = right colic artery; – = JA has no accompanying LyVe (the neighboring JAs do have); distances are from the midpoint of one entity to the midpoint of the other one.

[a]The mean overall external diameter of JAs was 5.5 ± 1.1 mm, whereas the mean ICA and MCA external diameters were 5.8 ± 1.6 and 4.8 ± 0.8 mm, respectively. The mean ICA-MCA distance was 27 ± 8.9 mm.

[b]"0.00" indicates that LyVe is leveled with the JA.

TABLE 2. Distances between the origins of ICA-JA and their calibers, derived from the 3D-CT reconstruction of the vascular anatomy

Variable	*ICA*	*MCA*	*JA1*	*JA2*	*JA3*	*JA4*	*JA5*	*JA6*	*JA7*
N (%)	101 (100)	101 (100)	0	12 (11.9)	21 (20.8)	31 (30.7)	21 (20.8)	13 (12.9)	3 (3)
Caliber,[1] mm	3.5 ± 0.9	3.2 ± 0.2	3.1 ± 1.0	3.2 ± 1.1	3.1 ± 1.1	3.3 ± 0.9	3.3 ± 1.0	3.0 ± 1.1	2.9 ± 0.3
ICA distance, mm		25.4 ± 11.2	10.9 ± 5.7	21.4 ± 9.0	30.2 ± 11.1	39.1 ± 13.5	43.7 ± 9.7	50.6 ± 10.2	47.6 ± 9.4

3D = 3-dimensional; ICA = ileocolic artery; JA = jejunal artery; MCA = middle colic artery.

drainage. The entirety of the lymph vessels from the SB ascended along the SMA in the form of a sheath. Within a synoptic view of the surgical trunks of the SMV and SMA, the lymph vessels generally followed the respective arteries, which resulted in a much denser and more intermingled lymph network on the side of the SB in comparison to the right colonic portion of the lymph drainage. Although this was a general pattern of jejuno-lymphatic trajectories, there were lymph vessels that crossed the neighboring JAs, bypassing the interarterial "slots" and mutually anastomosing. Jejunal lymph vessels were at an average of 1.5 ± 1.0 mm distance from their appropriate cranial JA. Additional data regarding the lymph vessel distance to the JA are shown in Table 1.

3D-CT Vascular Reconstruction Data Set

A total of 101 consecutive patients were included and operated on using our proposed technique (61 [60.4%] men, median age 62.5 [IQR 18] years).

Jejunal arteries. Detailed data regarding the caliber of the JAs and ICA-JA distances are shown in Table 2.

TABLE 3. Descriptive statistics for the entire sample and the JA groups, derived from the 3D-CT reconstruction of the vascular anatomy

Groups	*N (%)*	*Caliber, mm*	*JA med*	*JA cranial*	*JA caudal*	*ICA-MCA*	*ICA-JA1*	*JA1 to 2*	*ICA-SJA*	*MCA-SJA*
Entire sample	101	3.2 ± 0.7	4 (IQR = 2)	2	2	25.5 ± 11.2	10.9 ± 5.7	10.6 ± 5.7	43.9 ± 13.7	18.3 ± 17.1
Group A	81 (80.2)	3.2 ± 0.7	4	2	2	24.4 ± 9.6	10.3 ± 5.4	11.1 ± 5.7	45.0 ± 13.8	21.2 ± 15.7
Group B	13 (12.9)	3.1 ± 0.7	4	X	4	35.8 ± 13.9	9.8 ± 3.9	8.4 ± 4.6	34.8 ± 11.7	−6.0±5.3
Group C	7 (6.9)	3.6 ± 0.4	4	4	X	19.1 ± 11.1	19.7 ± 3.5	9.4 ± 7.9	45.4 ± 10.0	24.6 ± 16.1

All data are given as n (%), median (IQR) or mean ± SD.
3D = 3-dimensional; ICA = ileocolic artery; ICA-JA1 = distance between the ICA and 1st JA origins; ICA-MCA = distance between the ICA and MCA origins; ICA-SJA = distance between ICA and SJA origin; IQR = interquartile range; JA = jejunal artery; JA1-2 = distance between the 1st and 2nd JA origins; JAs caudal = median number of JAs caudal to the MCA; JAs cranial = median number of JAs cranial to the MCA; JA med = median number of JAs cranial and caudal to the MCA; MCA = middle colic artery; MCA-SJA = distance between MCA and SJA origins; MD = mean difference between JA groups; SJA = superior JA; x = arteries not observed.

TABLE 4. Distances between ICV-JV origins and their calibers

Variables	*JV1*	*JV2*	*JV3*	*SJV*
N (%)	38 (37.6)	52 (51.5)	11 (10.9)	101 (100)
Mean caliber, mm	9.2 + 5.1	8.5 + 2.3	5.5 + 1.6	9.3 + 5.1
ICV-JV, mm	19.5 + 9.0	34 + 11.5	47.3 + 13.5	31.2 + 13.8
Ventral course	33 (32.7)	16 (15.8)	7 (6.9)	29 (28.7)
Dorsal course	68 (67.3)	47 (46.5)	4 (4)	72 (71.3)

ICV = ileocolic vein; JV = jejunal vein; SJV = superior JV.

A total of 31 patients (30.7%) had a median of 4 (IQR, 2) JAs. A minimal number of 2 JAs was found in 12 (11.9%) cases, whereas the maximal number of 7 JAs was present in 3 (3%) cases. The mean JA caliber was 3.2 ± 0.7 mm. A low MCA origin was found in 4 patients (3.9%), whereas a high ICA origin was found in 2 patients and a common ICA-MCA trunk in 1 patient.

The groups A, B, and C. Detailed data on JA anatomy for each group are shown in Table 3. The mean differences for the ICA-MCA distances between the groups were:

- Group B and group A: 11.4 mm.
- Group A and group C: 5.3 mm.
- Group B and group C: 16.7 mm.

Jejunal veins. The median (IQR) number of JVs was 2 (1). The mean JV caliber was 9.3 ± 4.9 mm. In total, 57 JVs (56.4%) an dorsally to the SMA, 16 (15.8%) ran ventrally, and 28 (27.8%) had a combined course. The SJV confluence was cranial to the MCA origin in 67 (66.3%) cases and caudal to the MCA origin in 34 (33.7%) cases. The IMV drained to the SMV in 53 cases (52.5%), splenic vein in 44 (43.6%), and SJV in 3 (3%) cases; in 1 case, it was ligated because of prior surgery. Additional data on the caliber and JV-ICV distances for the individual JVs are shown in Table 4.

DISCUSSION

The most important findings of the present study are the results acquired through anatomical dissection, namely JA lymphatic clearance and their pattern of propagation within the mesentery. Several points of discussion have been identified. Rouvière et al[20] reported that each mesenteric artery was accompanied by 2 lymphatic vessels; however, data on their spreading patterns were not provided. Our results show that lymphatic clearance is minimal at the origin of JA, with radial spreading thereafter. A second point of interest is the denser and more intermingled lymphatic system (as opposed to the right colon), implying possible spillage of lymph to bundles of adjacent arteries, as described by Hollinshead.[8,13] Compared to our previously published results on the lymphatic clearances of the right colon arteries (2.8–6.3 mm), the JA clearances were significantly lower (up to 3.1 mm).[5] However, JAs are more abundant, the distances between JA origins are lower, and the lymphatic network is denser than that of colic arteries.

According to our results, lymphatic clearance seems to be most contiguous (vicinal) at the JA origins, thereafter spreading radially within the mesentery and interconnecting with the lymphatics of the adjacent JAs. The dissection results also demonstrated that a significant collector lymphatic channel flows along the left-hand side of the SMA and serves as the boundary between the D2 and D3 volumes (for video see Supplemented Digital Content 1 at https://links.lww.com/DCR/C507).[18] The mentioned lymphatic vessel can often be a reason for lymph leakage and chylous ascites.[21] This allowed us to infer that tumor-feeding JA ligation should be performed at its origin to prevent lymphatic spillage and avoid transecting the interconnecting lymphatics mentioned earlier. The removal of the collector lymphatic channel is included in the removal of the D2 and D3 volume.[5] Possible lymphatic leakage due to the removal of this collector lymphatic channel is not from the intended resection performed but rather from

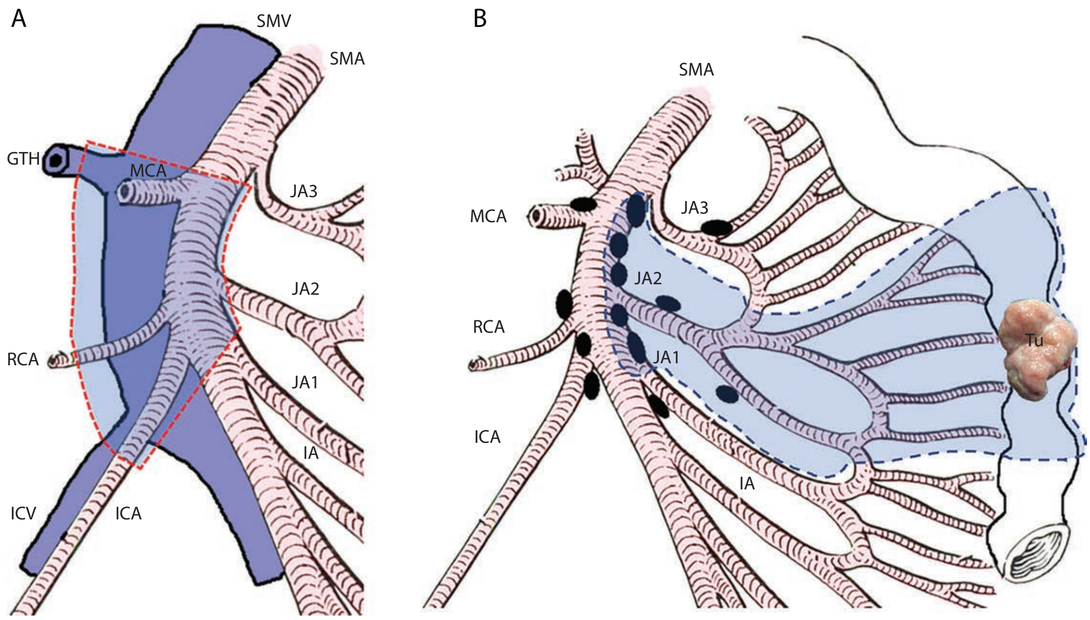

FIGURE 3. The D2 and D3 levels of dissection and the proposed technique of extended mesenterectomy. A, The red line represents D3 volume defined previously by Spasojevic et al and Nesgaard et al.[5,22] B, The blue line represents the proposed D2 volume with dissection along the JAs proximal and distal to the first arcade. GTH = gastrocolic trunk of Henle; IA = ileal artery; ICA = ileocolic artery; ICV = ileocolic vein; JA = jejunal artery; JV = jejunal vein; MCA = middle colic artery; RCA = right colic artery; SMA = superior mesenteric artery; SMV = superior mesenteric vein; TrMeCo = transverse mesocolon.

the "rest" of the SB. However, there is no risk of chylous ascites as a complication if a strict 3-day fat-free postoperative diet is applied.[21] A further preemptive move to ensure an adequate level of dissection II lymphadenectomy would entail the removal of the mesenteric fatty tissue along the adjacent JAs to the level of the first arcade (Fig. 3). This provides maximal preservation of the SB while warranting an appropriate lymphadenectomy.[23] If removal of the fatty mesenteric tissue around the superior mesenteric vessels (D3 volume[22]) is attempted, the identification of the ICA and JAs is achieved first. The tumor-feeding vessel can then be ligated at its origin. LN dissection along the proximal/distal JAs from their origin to the first branch can be performed "en bloc." This challenges the traditional concept of SB wedge "pizza-pie" resection and has shown favorable results when treating patients with right colon cancer with positive central LN (D3 volume) metastasis.[12,24] The lessons from the right colon lymphatic anatomy have proven an important LN yield in the D3 volume.[22]A correlation can be drawn with the SB, as their mesenteries are a single continuous structure.[25]

The second point is the proposed classification of JAs into 3 groups, which is practical and aims to simplify the anatomy for surgeons. Multiple arteries in a tiny area of the central mesentery (D3 volume), with small distances between their origins and a parallel trajectory, can often cause confusion and hesitation when identifying tumor-feeding vessels. Although it is considered advantageous to have a 3D reconstruction of the patient's vascular anatomy, the surgeon can study the staging CT himself and classify the patient into one of the 3 groups, thereby facilitating orientation during surgery.[26,27] From the presented ICA-MCA distance mean differences, group B has the longest intercolic interval and could imply that all JA origins lie caudal to the MCA origin, a preferable option to group C where JA origins lie exclusively cranial to the MCA origin and pancreatic notch. Hence, the ICA and MCA present an important landmark for the quick orientation to the anatomical group. Furthermore, other anatomical relations can be established, such as distances from the ICA to the JAs, the tumor-feeding vessel, as well as the crossing pattern of the JVs to the SMA as shown in Tables 2–4. Occasionally, intestinal lymphatics can be visualized.[18]

The importance of JVs lies in their caliber and trajectory. Although the importance of the JV caliber is due to possible hemorrhage, the question of JV ligature needs to be addressed. Matthews and Kobayashi stated that the SJV (the most cranial JV trunk from the ICV origin) could be ligated without clinical consequences. While Kobayashi postulates a 7 mm cutoff for JV caliber for safe ligation to prevent congestion, Katz states that one of the 2 first-order branches of the SMV can be ligated safely as long as the distal SMV is preserved.[28,29] However, no data on the position of this ligation have been reported. Literature states that thrombosis in large veins can occur when the ligature of a tributary is not performed at its confluence, that is, leaving a longer stump.[30,31]

The JV trajectory is more important when operating on jejunal tumors in comparison to pancreatic surgery.

A surgeon operating on a jejunal tumor can identify the JV with a trajectory crossing the intended mesenterectomy site, requiring ligation. The lymphovascular bundles of the mesentery follow the arteries and not the veins.[5,22] Consequently, the ligation point of JV does not influence D2 or D3 dissection, and routine ligation is not recommended. However, if ligation is unavoidable, it should be performed at its confluence to avoid long stumps and subsequent thrombosis. In addition to this oblique trajectory, JVs can cross the jejunal tumor-feeding JA ventrally, dorsally, or from both sides. As shown in our results, these variants can be identified using 3D vascular reconstruction of the anatomy. Our results are in accordance with previously published data, with the contribution of the JV confluence position to that of the ICV and to the origin of the MCA.[19,28,32] These data can aid the operating surgeon in selecting the correct structure for ligation. Although Nesgaard et al[19] reported that the IMV drains directly into the SMV in 41.4% of the cases, the present study showed a somewhat higher occurrence (52.5%).

SB tumors are infrequent pathology with various tumor types, making it not feasible for a randomized trial. The procedure can be tested as a cohort. Due to the rare occurrence of tumors in the jejunum, centralizing this surgery would be advantageous and could lead to better outcomes despite a slightly longer operative time.

Extended mesenterectomy is a bowel-preserving technique with a low risk of additional SB segment loss. However, dissection in the central mesentery does increase the risk for vascular injury and consequent bleeding, increasing the value of the 3D reconstruction of the anatomy that prevents injuries and provides solutions when such injuries occur.[26,27]

The 3D reconstruction is derived from the preoperative staging CT. The surgeon can orient himself on the anatomy by following the vessels on the CT, and the data that we presented should facilitate the orientation. In contrast, institutions are offering commercial individual patient anatomy reconstructions. Semiautomated reconstruction has a clear advantage due to its rapid production of 3D virtual models. However, it still provides inferior results compared to manual segmentation. It is expected that with the incorporation of artificial intelligence, the reconstructions could improve, incorporating labeling of vessels.[33]

Chemotherapy differs according to the pathology. Most of these are neuroendocrine tumors that do not receive chemotherapy. The next group, according to size, is adenocarcinomas, which have a poor prognosis and should receive chemotherapy. Other tumors are lymphomas, metastases, and so on with a specific treatment protocol.

Although the oncological benefit of complete mesocolic excision/D3 has not provided solid proof in the context of long-term survival, there are several case series indicating the possibility, especially in advanced disease.[12,34,35] Taking this into account and the fact that the frequency of colon cancer is high compared to that of the SB, it does not come as a surprise that similar data for the SB cannot be found in the literature. We provide the data and the rationale for the surgery of the jejunal tumors, which we are performing in an ongoing clinical trial. Preliminary and unpublished results only provide an insight into the harvest of 24 LNs (18–46); of these, 17 (13–21) were in the D3 volume.

The strength of this study lies in the meticulous anatomical dissection performed by 2 anatomists (M.B.S. and B.V.S.). A weakness is that the LNs were not counted during dissection because the main observation was the position of the lymph vessels. The sample size for anatomical dissection was small but adequate for the conclusions drawn. Another strength is the 3D reconstruction of vascular anatomy verified during surgery, which represents an adequate sample size. The combination of these 2 complementary methodologies is a strength that permits the extrapolation of data to surgical techniques.

CONCLUSIONS

Minimal JA lymphatic clearance implies ligation of the tumor-feeding vessel at its origin. The dense and more intermingled lymphatics along the JAs imply LN dissection along the proximal/distal vessel to the level of the first arcade. The proposed classification of JAs and JVs has the potential to simplify the anatomy for surgeons. The findings of this study seem to support our proposed technique for extended mesenterectomy in the treatment of jejunal tumors.

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