JOP. J Pancreas (Online) 2017 Jul 31; 18(4):320-326.

ORIGINAL ARTICLE

Mapping of the Superior Mesenteric Vessels for Artery First Pancreatoduodenectomy in Patients with High Visceral Fat

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ABSTRACT

Background No studies have reported the impact of visceral fat on anatomy of the superior mesenteric vessels. We aim to clarify the anatomical relationships between the superior mesenteric artery, vein and their tributaries relative to levels of patient visceral fat to assess applicability of artery first pancreatoduodenectomy in obese patients. **Methods** 176 triple-phase computed tomography scans were retrospectively analysed to determine the positioning and distance of the superior mesenteric artery relative to the superior mesenteric vein at varying levels, and to jejunal veins. Patients were categorised into high and low visceral fat groups based on mean sagittal abdominal diameter. Hypothesis testing was performed to highlight anatomical differences. **Results** No statistical significance was found to suggest that either the distance between superior mesenteric artery and superior mesenteric vein (at gastrocolic trunk level), or the distance between superior mesenteric artery and ventral jejunal vein varied with level of visceral fat ($p=0.26$ and 0.08, respectively). Superior mesenteric artery originating caudal to the spleno-mesenteric confluence was significantly more prevalent in high visceral fat ($n=80$) patients compared to low visceral fat ($n=96$) patients (24% *vs.* 6%, $p<0.05$). **Conclusion** Superior mesenteric artery access during artery first pancreatoduodenectomy appears to be as feasible and safe in obese patients as in non-obese individuals.

INTRODUCTION

The artery first pancreatoduodenectomy (AFPD) is an established approach to treat tumour of the head of pancreas. Historically, superior mesenteric vein (SMV) or portal vein (PV) invasion has been the central factor in determining the resectability of pancreatic head tumours, but the transition towards AFPD in the last two decades reflects the now accepted practice that the main determinant of resectability should be degree of arterial involvement, rather than that of SMV or PV [1].

The concept of borderline resectable pancreatic cancer (BR) is key, and was originally defined by the American National Comprehensive Cancer Network (NCCN). In essence, cases of BR have SMV or PV involvement with encasement of the gastroduodenal or hepatic arteries, or abutment of the SMA (no more than 180 degrees) [2]. Such patients should be considered for curative resection. Therefore, a main advantage of the AFPD approach is the early determination of tumour resectability prior to embarking on any irreversible intraoperative steps, potentially preventing futile surgery with high rates of morbidity and mortality.

Received May 01st, 2017 - Accepted June 16th, 2017
Keywords Intra-Abdominal Fat; Mesenteric Artery, Superior; Mesenteric Veins; Pancreaticoduodenectomy
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Another recognised advantage of AFPD is the relative reduction of intraoperative blood loss [3, 4], likely due to the early identification and ligation of the inferior pancreaticoduodenal artery (IPDA) and other pancreatic branches of the SMA.

A further benefit of AFPD appears to be that of intraoperative exposure. Reporting on their experiences of using an artery first mesenteric approach, Hirono and Yamaue outlined that by firstly incising the mesojejunum to reveal proximal jejunal branches of the SMA and IPDA, subsequent division of these vessels allowed a more comprehensive dissection of lymph nodes and the nerve plexus adjacent to the SMA [5]. This may be a significant advantage in achieving better oncological outcomes in the BR patient subset.

"Isolated" en-bloc resection requiring control of all afferent and efferent vessels to the target tumour or organ before manipulation or mobilisation to prevent seeding is a measure utilised in many specialties. Nakao on the background of more than 30 years' experience, highlights the comparatively superior ability to carry out an "isolated" resection using the mesenteric AFPD approach [6]. The author further emphasises early diagnosis of resectability in AFPD.

With the numerous advantages conferred by AFPD in mind, we consider the anatomical implications. Several approaches to the AFPD have been described in literature [1], but intimate knowledge of key landmarks is universally mandatory. For example, the gastrocolic trunk of Henle (GCT) and middle colic artery (MCA) are widely used in the recognition of the SMV and IPDA, respectively [7, 8]. Variable quantities of visceral fat have previously been highlighted as a possible barrier to the intraoperative identification and dissection of these landmark vessels, including the GCT [7]. Therefore, it is logical to conclude that this is of substantial clinical significance when performing AFPD on certain patient populations, such in the UK where two-thirds are overweight or obese [9]. This is especially so when previous studies, including Janssen *et al*. [10], have positively correlated body mass index (BMI), and therefore clinical obesity, to quantity of visceral fat.

It is known that quantity of visceral fat significantly relates to the distance between the SMA and aorta [11]. However, to our knowledge, there are no studies currently which report the impact of visceral fat on the anatomical relationships among the landmark vessels involved in AFPD. Such information may substantially inform future preoperative planning and intraoperative decision making. Furthermore, we note that the previously mentioned Japanese studies included mainly non-obese patients and it is unknown whether the clinical outcomes could be attributed to lower levels of visceral fat.

The aim of this study, therefore, was to correlate the anatomical relationships between the SMA, SMV and their tributaries with special focus on the impact of patient visceral fat.

METHODS

Between April 2016 and August 2016, 200 consecutive triple phase CT scans of the abdomen were performed in our institution to investigate liver disease. For the purposes of this study, 17 cases were excluded due to pathology distorting the normal intra-abdominal anatomy. These included 5 cases of ascites, 2 cases of portal hypertension, 1 case of liver cirrhosis, 4 cases of disseminated malignancy, 1 case of previous major liver resection, 1 case of severe pancreatitis and 3 cases of severe congenital abnormalities (including scoliosis, chest wall deformity and situs inversus). A further 5 cases of inadequate visualisation of landmark vessels, and 2 cases where the CT scan was performed as part of an interventional procedure, were also excluded.

Each of the 176 CT scans included in the study was interpreted by two experienced hepatopancreaticobiliary surgeons using a radiology workstation monitor. Consensus was reached during the interpretation of each CT, and the surgeons were blinded to the radiology reports as well as the patients' medical background.

In this study, we used a modified Fullen's classification in order to separate the SMA into distinct segments [12]. Most proximally, segment 1 is defined as SMA running from its origin in the aorta to branching of the IPDA. Segment 2 is between branching of IPDA to branching of the MCA. Segment 3 extends distally from the MCA division, encompassing the origins of segmental jejunal and ileal arteries. From this, we analysed the anatomical position of individual segments in relation to the SMV and its tributaries.

Firstly, we studied the position of segment 1 of the SMA in relation to the spleno-mesenteric confluence (SpMC). The position of segment 3 relative to that of the SMV at the level of the third part of the duodenum (D3) was also studied. Using these observations, we propose a new anatomical classification which illustrates the unique combination of relationships between SMA, SMV and its tributaries in different patients. Specifically, in cases where segment 1 of the SMA was found to be postero-medial to the SpMC, we designated this as a type I relationship **(Figure 1a)**. In others where segment 1 was either directly posterior the SpMC, or the SMA origin was caudal to the SpMC, these were defined as type II and type III, respectively **(Figures 1b, 1c)**.

In a similar fashion, segment 3 of the SMA lying medial, postero-medial and posterior to the SMV at D3 level were designated as subtype a, b and c relationships, respectively **(Figure 2)**.

We also focused on two additional clinically relevant anatomical parameters. The soft tissue separating the SMA and SMV ("SMV groove" for the purposes of our analysis and discussion) was examined in all cases **(Figure 3a)**. The thickness of the SMV groove was measured at the level of the gastrocolic trunk. Furthermore, we studied the patterns of the proximal jejunal vein (JV), along with the thickness of the soft tissue separating this and the SMA in cases where JV was present ventrally. We have termed this distance the "JV groove".

Previous studies have demonstrated the value of sagittal abdominal diameter (SAD) both as a reliable predictor of visceral fat mass [13] and indicator of intraabdominal operative complexity [14]. Therefore, this method was used to radiologically categorise all patients in this study into either low (LVF) or high (HVF) visceral fat groups, achieved by calculating the mean SAD and subsequently designating each patient accordingly by this threshold. The SAD of each patient was determined on axial CT by measuring the midline anterior-posterior thickness of the abdomen at the level of the fourth lumbar vertebra **(Figure 3b)**. Analysis of correlation between visceral fat level, the subgroups of our anatomical model and JV/SMV groove thickness was carried out.

All statistical analyses were performed using SPSS version 24.0 (IBM Corp. 2016, Armonk, New York). Nominal data was examined using a chi-squared test, and student's T-test was used for all continuous data sets. As standard, a p-value of less than 0.05 was considered to be statistically significant. Summary of all continuous data was expressed as mean standard error of the mean.

The local research committee confirmed that formal ethical approval was not required for this study.

RESULTS

The study population consisted of 98 females and 78 males, ranging in age from 24 years to 92 years. Median age was 67 years. In all 176 patients, segments 1 and 3 of the SMA were visualised relative to the SpMc and SMV at D3 level, respectively.

The majority of patients in general (76%) demonstrated a type I relationship where SMA lied postero-medial to the SpMc **(Table 1)**. Type II relationship was seen in 18 patients (10%), and type III in the remainder (14%). At the level of the third part of duodenum, the SMA was found to be medial to the SMV (subtype a relationship) in 78% of all cases. Subtype b relationships were seen in approximately 20% of all patients, and instances where SMA was found to be directly posterior to the SMV at D3 (subtype c) represented only 2% of all cases.

Mean SAD of the 176 patients was 242 mm ± 49 mm. 80 patients with SAD of over 242 mm were therefore classified as having high visceral fat (HVF) and the remaining 96 individuals were placed into the low visceral fat group (LVF).

Combining the above classifications in our analyses, a type III association between SMA and SpMC was significantly more prevalent amongst the HVF group (24% *vs.* 6%, $p<0.05$). Equal prevalence (10%) of type II relationships was found in the two visceral fat groups. Type I association was seen in 83% of LVF patients and 66% of HVF patients **(Table 1)**.

Rates of subtype a relationship were comparable between the HVF and LVF groups (80% *vs.* 76%). Subtype b associations were observed in 16% of HVF patients and in 23% of the LVF group. Subtype c associations were found in 4% of the HVF patients and 1% of the LVF patients **(Table 1)**.

No statistical significance ($p=0.26$) was demonstrated when we applied Student's T-test in regards to SMV groove thicknesses in the HVF (3.7 mm ± 2.8 mm) and LVF (3.2 mm ± 2.0 mm) patient tiers **(Table 2)**. Similarly, JV groove thicknesses in the HVF (0.62 mm ± 1.03 mm) and LVF (0.43 mm ± 0.80 mm) patients were not significantly different ($p=0.08$).

DISCUSSION

Out of 176 CT scans, a 10% prevalence of Type II relationship between the SMA and SpMC was found among all patients, with equal distribution in the HVF and LVF groups. By definition of AFPD, exposure of the SMA is a challenge in patients where this vessel is directly posterior to the SpMC or SMV. This is especially the case when using either a mesenteric (infracolic) or anterior (supracolic) approach, with the latter technique favoured by the authors. Therefore, in this minority of patients, more extensive mobilisation of the SpMC may be required to provide additional retraction while exposing the SMA

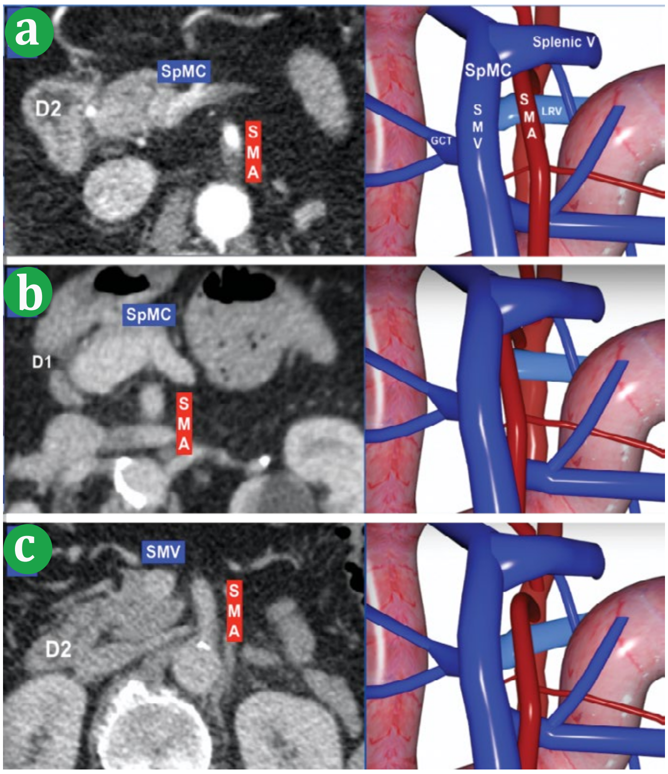

Figure 1. Axial CT images and corresponding models for types of SMA segment 1/Spleno-mesenteric confluence (SpMC) relationships. **(a).** Type I relationship where the SMA lies postero-medial to the SpMC. **(b).** Type II relationship where the SMA lies posterior to the SpMC. **(c).** Type III relationship where the SMA origin lies caudal to the SpMC. **LRV -** Left renal vein.

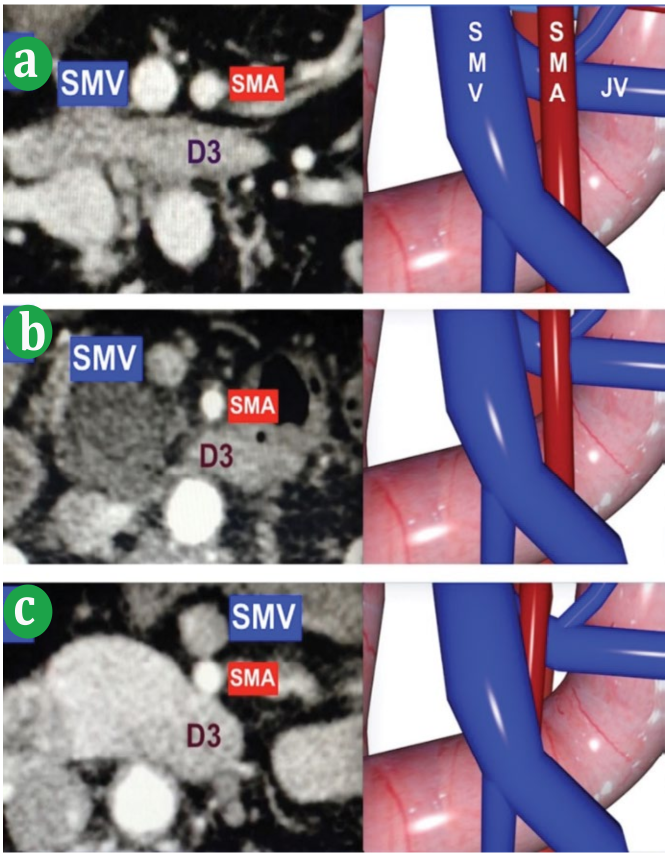

Figure 2. Axial CT images and corresponding models for SMA segment 3/D3 level SMV relationship. **(a).** Subtype a relationship where the SMA lies medial to the SMV. **(b).** Subtype b relationship where the SMA lies postero-medial to the SMV. **(c).** Subtype c relationship where the SMA lies posterior to the SMV. **JV** - jejunal vein.

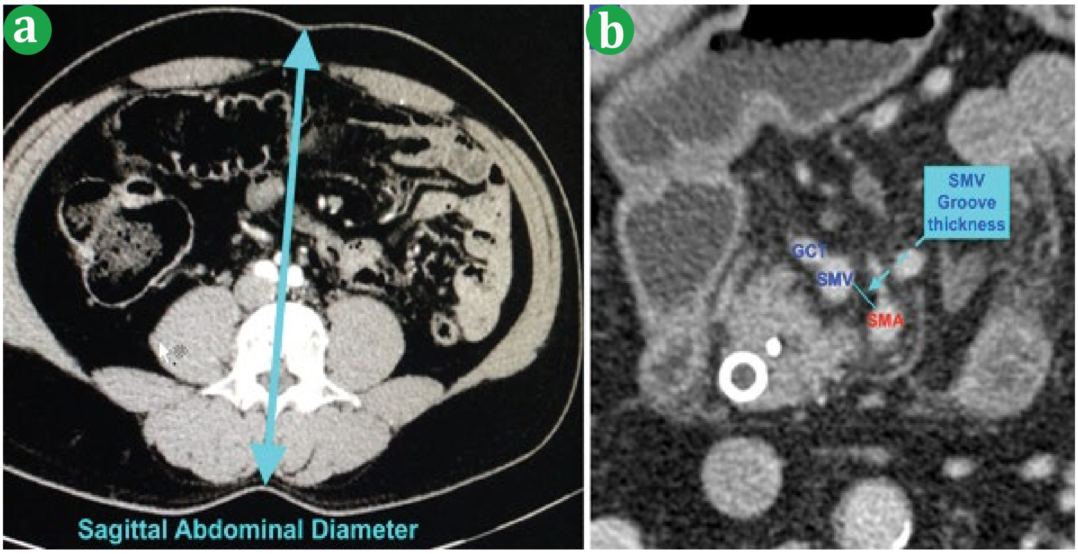

Figure 3. (a). Determination of sagittal abdominal diameter (SAD) on axial CT. **(b).** Measurement of SMV groove thickness.

Table 1. Distribution of patients within the high/low visceral fat groups and anatomical classifications

	HVF N=80	LVF N=96	Total N=176
Type-I	53 (66%)	80 (83%)	133 (76%)
Ia	48	68	116
Ib	3	12	15
Ic	2	0	2
Type-II	8 (10%)	10 (10%)	18 (10%)
IIa	3	0	3
IIb	5	9	14
IIc	0	1	1
Type-III	19 (24%)	6 (6%)	25 (14%)
IIIa	13	5	18
IIIb	5	1	6
IIIc	1	0	1

Table 2. Superior Mesenteric Vein (SMV) Groove and Jejunal Vein (JV) Groove thickness in high and low visceral fat patients.

	HVF N=80	LVF N=96	T-test p-value
	Mean ± SE (mm)	Mean ± SE (mm)	
SMV groove	3.7 ± 2.8	3.2 ± 2.0	0.26
JV groove	0.62 ± 1.03	0.43 ± 0.8	0.08

(Figure 4a). In some cases early division of the pancreatic neck is indicated to facilitate better exposure.

In the majority of patients (76%), a type I relationship was demonstrated. The AFPD approach is easier in these patients and requires less aggressive mobilisation of the SpMC, if at all **(Figure 4b)**.

In this series, we identified a significantly higher proportion of type III relationships in HVF patients. As the SMA origin lies caudal to the SpMC, the proximal part of the artery is once again relatively more accessible compared to patients with type II anatomy. Interestingly, a previous cadaveric study showed that in 9% of individuals, the external distance between the coeliac trunk and SMA origin was greater than 10 mm [15]. This variation may account for some of the type III patients observed in our study. However, it is not clear why significantly more type III relationships are seen in patients with higher levels of visceral fat. Clearly, one possibility is that this observation is simply due to greater mechanical displacement of the SpMC by visceral fat in the cephalad direction. Further detailed *in-vivo* radiological studies are needed to delineate this.

Other than posterior placement of the SMA, another barrier to the anterior AFPD is degree of SMV groove thickness. This is because it is more challenging to accurately define a plane between the SMA and SMV in the presence of abundant soft tissue, namely additional adipose, between the two structures. In this study, we found no significant statistical evidence to suggest correlation between quantity of patient visceral fat and SMV groove thickness. To our knowledge, this is the first time such has been reported. We conclude that in this regard, access to SMA in anterior approach AFPD is as feasible in obese (HVF) patients as non-obese patients.

In our experience, the advantages of an anterior approach are multiple. In this method, virtually no mobilisation of duodenum is required, and following division of the gastrocolic ligament and access into the lesser sac, the right gastroepiploic vein (RGEV) is easily identified. RGEV is subsequently traced to the GCT and SMV **(Figure 5a)**. With usually minimal retraction of the SMV, the SMV groove is exposed and incised along the longitudinal axis **(Figure 5b)** to reveal the ventral surface of SMA **(Figure 5c)**. The IPDA is subsequently identified and ligated **(Figure 5d)**.

The proximal jejunal vein (JV) is another established landmark in orienting the dissection of SMA. A 2013 series by Nakamura et al. found that AFPD based on JV oriented dissection significantly reduced intraoperative blood loss [16]. However, one main issue is that the JV does not represent a permanent anatomical fixture and in our 176 cases, one or more JV ran ventrally to the SMA in 32% of patients (56/176). This is consistent with previous reports [4, 17], although considerable variation exists [18, 19]. Extending the above description of our approach to SMA dissection, in patients with JV, the plane between this vessel

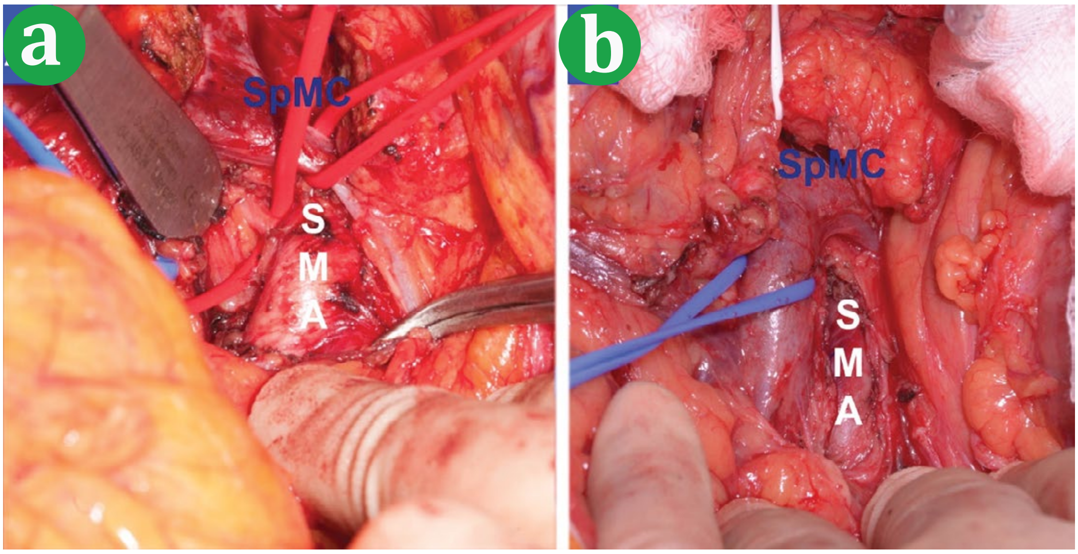

Figure 4. Intraoperative dissection of the SMA. **(a).** In a type II relationship, the SpMC is retracted away from the SMA following its mobilisation. As in this case, early division of the pancreatic neck facilitates this manoeuvre. **(b).** With a type I relationship, exposure of the SMA does not necessitate mobilisation of SpMC.

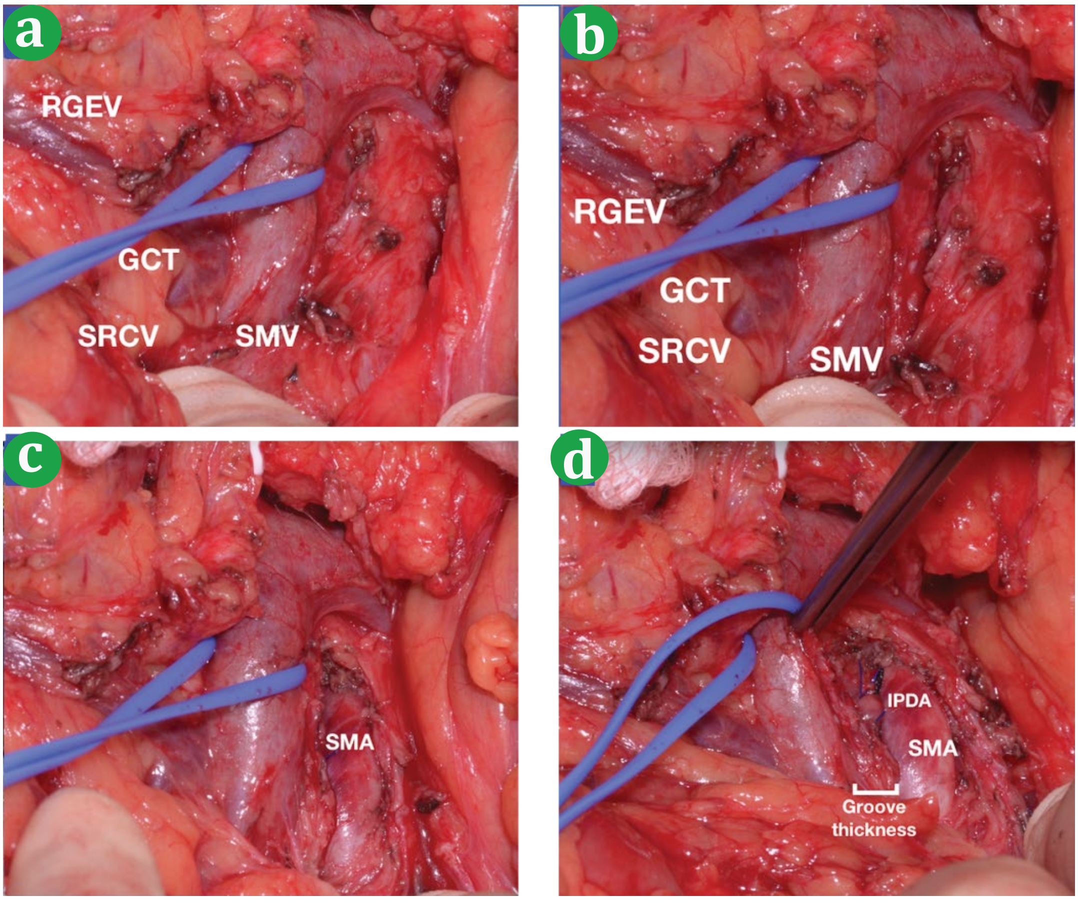

Figure 5. (a). Recognition of the RGEV, which can be followed to the GCT and SMV. **(b).** With gentle lateral retraction of SMV, the SMV groove is revealed and incised parallel to the vessels. **(c).** Exposed ventral surface of SMA. **(d).** Identification and ligation of IPDA. **SRCV -** superior right colic vein.

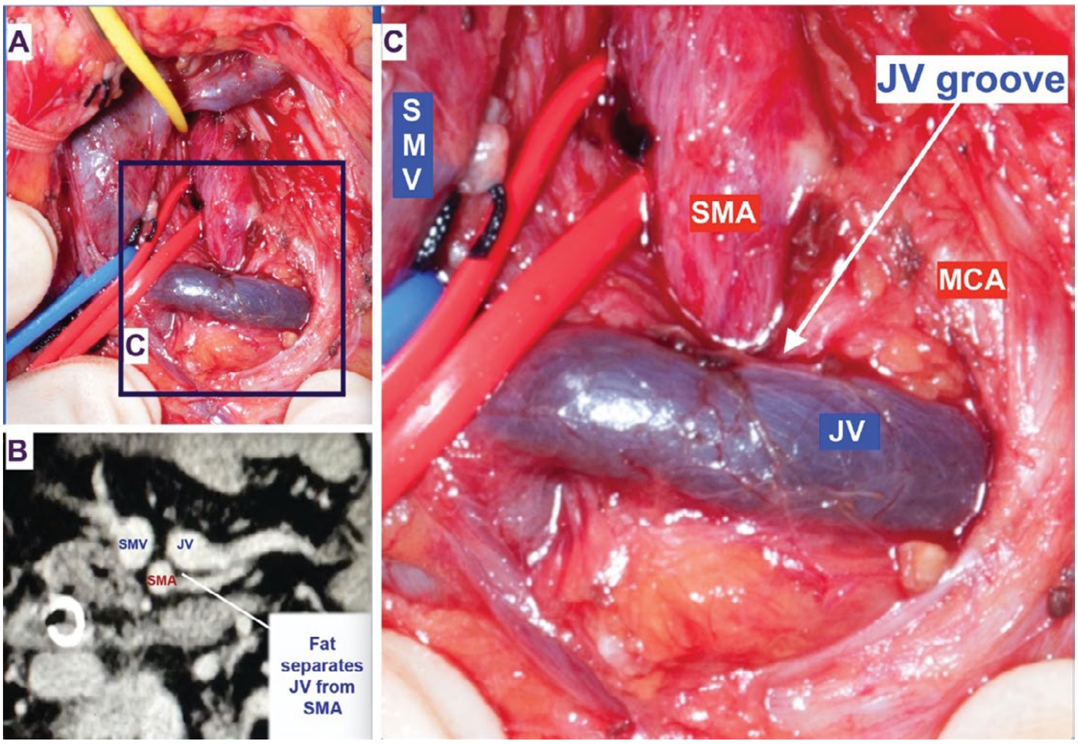

Figure 6. (a). Dissection of the SMA in the presence of a ventral running JV. The JV groove demonstrated here offers a window to access the ventral SMA. **(b).** Preoperative CT mapping identifies presence of JV. **(c).** Magnified image of JV and the JV groove.

and the SMA (the JV groove) provides a natural window of access to the ventral SMA **(Figure 6)**. Nevertheless, as with the SMV groove, surplus visceral adipose within this location complicates the dissection. Once again, our analysis found no statistically significant evidence to suggest that this is the case in HVF, or obese individuals. As with the SMV groove, this appears to support the conclusion that SMA access is not more challenging in obese individuals with ventral JV during anterior dissection.

From experience, we generally find that dissection of the JV groove is easiest when this distance is no greater than 1 mm. In this series, of all HVF patients with CT confirmed ventral JV (19/276), the majority (53%) had a JV groove thickness of 1 mm or less, with a third (6/19) demonstrating direct contact between the ventral JV and SMA.

CONCLUSION

In this study, we highlight several key anatomical findings which have not been previously reported. Most notably, we found that there was neither a correlation linking sagittal abdominal diameter, a reliable marker of visceral fat level, and distance between the SMV and SMA at the level of the gastrocolic trunk, nor a correlation linking sagittal abdominal diameter and visceral fat quantity with the distance between the SMA and ventral JV, where this is present. These findings suggest that the anterior approach AFPD, where emphasis lies on demonstrating the ventral SMA, is safe in obese patients, and should not be hindered by the presence of extra visceral fat.

We also report that caudally originating SMA is more frequently seen in high visceral fat individuals. Although clinically significant, the underlying reason for this is not certain. This paves the way for future work.

Through our novel anatomical classification, we report that in comparison to most individuals, isolation of the ventral SMA is likely to be more challenging in the small proportion of patients with a posterior lying SMA, where more dynamic intraoperative manoeuvres may be required.

Acknowledgement

This article/abstract has been accepted for oral presentation at Association of Surgeons of Great Britain and Ireland (ASGBI) Congress 2017, 3rd to 5th May 2017, Glasgow, UK.

Conflict of Interest

The authors declare that they have no conflict of interest.

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