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Anatomical branches of the superior rectal artery in the distal rectum

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Running head: Distal branches of superior rectal artery

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Abstract

Objective: The aim of this experimental study was to study the arterial supply of the corpus cavernosum recti in the inner wall of the distal rectum in relation to hemorrhoidal ligation therapy.

Methods: In ten non fixed human cadavers the arterial vasculature of the rectum was studied using the Araldite casting method. Subsequently, the specimens were treated with methylbenzoate in order to obtain semitransparent specimens in which the corpus cavernosum recti could be studied.

Results: Specimens were obtained permitting study of the arterial vasculature of the rectum and corpus cavernosum recti at all levels. The superior rectal artery was found to supply the corpus cavernosum recti which consisted of a variable number of equally spaced twisting arteries.

Conclusion: The distal rectum is supplied by the superior rectal artery. The supplying arteries of the corpus cavernosum recti are not confined to the strict locations described in the literature. This finding is of importance in surgical treatment of hemorrhoidal disease.

Introduction

The prevalence of hemorrhoidal disease ranges from 4% to 86% of the population [1,2], with a male : female ratio of 1: 4 [3]. Hemorrhoidal tissue forms part of the anal continence mechanism in the anal canal and distal rectum. When non-symptomatic it is referred to by the term ‘anal cushions’ which consist of vascular tissue in a stroma of connective tissue and smooth muscle fibres within the anal canal. The anal cushions fulfil four main functions [4]. By their approximation they contribute to anal canal closure and thus continence; they provide 15%–20% of resting anal pressure; they protect the sphincter mechanism during evacuation and they form a compressible lining, facilitating closure of the anal canal. The smooth muscle acts as a supportive structure forming a fibro-elastic network within the cushion plexus [2]. This structure was named by Stelzner *et al.* [5] as the corpus cavernosum recti also known as plexus hemorrhoidalis and is supplied by a complex structure of blood vessels.

Since the arterial blood flow in the internal hemorrhoidal plexus is thought to be associated with the pathogenesis of hemorrhoids, newer techniques have aimed to reduce the vascularity of the hemorrhoidal tissue. One such technique is hemorrhoidal artery ligation (HAL) or transanal hemorrhoidal dearterialisation (THD). The technique is based on Doppler identification and suture ligation of the submucosal terminal branches of the superior rectal artery in the corpus cavernosum recti. A special designed proctoscope with a fixed ligation window prevents sutures to be placed deeper than in the submucosal layer.

Several anatomical studies have concluded that the corpus cavernosum recti is exclusively fed by the superior rectal artery. A detailed account of the vasculature in the external rectal muscular wall layers was recently described by Aigner *et al.* [6], but the vascular anatomy of the internal lining of the distal rectum has not been studied. We investigated the anatomy in cadavers of the corpus cavernosum recti in the inner wall of the distal rectum and its relationship to the superior rectal artery.

Method

Specimens

Ten non-fixed human cadavers (7 male, 3 female; age range 60 to 87 years, mean age 75) were studied. The arteries of the rectum and the vascular territory of the superior rectal artery were injected with Araldite introduced into the superior rectal and the internal iliac arteries. The abdomen was opened and the inferior mesenteric artery was carefully dissected along its course to its division into the superior rectal arteries. A superior rectal artery was then cannulated and connected to a pump to inject the Araldite after clamping the external iliac arteries and the aorta to prevent leakage of Araldite into non-relevant areas.

Araldite casting

After preparation the vessels were filled with Araldite delivered by a pump, after connecting the Araldite reservoir with an electrical membrane valve pump with a needle valve for pressure control. The Araldite mixture consisted of Araldite DY G26SP, dilutant DY 026SP, hardener HY 2967 (Ciba Geigy, Basel, Switzerland) and differently coloured Mircolith-T pigments. Its temperature was maintained at approximately 10^{o} C to avoid premature hardening. Each artery was filled with a different coloured mixture as follows: superior rectal artery: green, left internal iliac artery: blue, right internal iliac artery: red. These arteries were simultaneously filled at a pressure of 160 mmHg, with each artery filled with a maximum of 40 cc Araldite. This volume was sufficient to fill the vessels adequately. After casting, the Araldite was allowed to set for at least 20 hours.

Dissection

In eight specimens the anorectum was carefully dissected for macroscopic examination. The specimen was removed from the pelvis and the connective tissue and fat were carefully removed for better visualization of the vessels (Fig. 1). The casted perirectal vessels were carefully dissected and the rectum was then opened longitudinally to study its internal lining.

Serial sectioning

The two remaining specimens were cut in serial sections to a thickness of 25µm and 50µm in a cryomicrotome (Model 450 MP, PMV, Stockholm, Sweden) after embedding in carboxymethylcellulose (CMC). After each section the surface of the tissue block was digitally imaged and processed for computerised reconstruction.

Tissue clearing

The eight specimens were subsequently placed in a series of alcohol solutions of increasing concentration (70%, 80%, 96% and 100%) to dehydrate the surrounding tissue and were then finally placed in methylbenzoate 98% to obtain semitransparent specimens to allow study of the casted vessels.

Araldite casting

Araldite casting in combination with tissue clearing provided three-dimensional preparations that were semitransparent since methylbenzoate has a refractory index which approximates to that of the tissue. In the cleared specimens the vascular system could be studied in detail throughout all levels of the bowel wall. Figure 2 shows an Araldite cast in a semitransparent specimen of the distal rectum. For optimal visualisation, specimens were transluminated. The green-coloured Araldite in the SRA contrasted clearly with the surrounding tissue.

Results

Spatial relations

Vessels were identified down to a diameter of 0.2 mm. The superior rectal artery followed the posterior aspect of the sigmoid colon and bifurcated about 12 cm (range 10 to 14 cm) cm above the dentate (pectinate) line (Fig. 3). The artery divided in three to five large branches. Each branch partially spiralled around the central axis of the rectum and subsequently separated into five to seven branches penetrating the bowel wall. No anastomosis greater than 0.2 mm between the branches was seen. The most distal branch of the superior rectal artery entered the bowel wall approximately four cm above the dentate line. This pattern showed little variation and most differences were observed in the branching pattern of the main stem of the superior rectal artery.

Internal lining of the rectum

About two to three cm above the dentate line, twisting arteries of maximum diameter 2mm and containing green Araldite were seen to emerge towards the mucosal surface (Fig. 4). These continued in the submucosa down to the dentate line where they diverged into smaller branches to form, to some degree, a plexus in the corpus cavernosum recti area. On average about eight arteries were seen in the distal rectum, all originating in the superior rectal artery (Fig. 3, 4). These vessels were circumferentially arranged with more or less equal distances between them. Only green Araldite was seen in the corpus cavernosum recti.

A small area at the level of the corpus cavernosum recti in the outer lining of the rectum showed vessels coloured with Araldite other than green. The area distal to the dentate line (pecten and skin) showed small branches coloured blue or red originating from the internal iliac arteries. These had their origin in the internal pudendal arteries which branch from the internal iliac arteries and were considered to be the inferior rectal arteries. In six specimens this inferior rectal artery was found either bilaterally or unilaterally. In none of the specimens could the middle rectal artery be identified.

Serial sectioning

The slice thickness of 25 to 50 µm enabled a high-resolution reconstruction. This showed a plexiform network (green) of supplying arteries in the rectum wall. Figure 5 is a still frame of the reconstruction video and shows a cross section with a vessel penetrating through the bowel wall.

Discussion

Our findings showed a detailed picture of the course of the superior rectal artery in the distal rectum to the anal verge. The alcohol tissue clearing technique proved to be suitable for producing transparent tissue specimens allowing a new and detailed picture of the vessel structure at the inner lining of the distal rectum to be constructed. Although the study was performed with hemorrhoidal ligation therapy in mind, it should be emphasised that none of the specimens were obtained from individuals known to have haemorrhoids. The anatomical changes in haemorrhoids were therefore beyond the scope of the study.

In our specimens we only found green coloured Araldite from the superior rectal artery in the corpus cavernosum recti region, indicating that the corpus cavernosum recti is solely supplied from the superior rectal artery as was found by Aigner *et al.* [6]. These vessels are of great importance especially in terms of oncological rectal resections, where those collateral arterial vessels originating from the inferior rectal artery are crucial for sufficient blood supply of the rectal stump [7]. The suggestion by Bursics *et al.* [8] that other vessels could penetrate the wall of the distal rectum and supply the corpus cavernosum recti can not be confirmed in our study.

There is no consensus regarding the presence of the middle rectal arteries with varying conclusions from different studies. Jones *et al.* [9] found a huge variation in the published data on the incidence of the middle rectal artery. This may have been due to differences in the definition of the middle rectal artery and the anatomical methods used to trace them. In all these dissection studies the possibility that the middle rectal artery accidentally removed cannot be ruled out. In our non-invasive study in which the casted vessels were all easily seen, we found few red and blue coloured branches in the outer layers of the rectum, below the level of the levator ani muscle. We assumed this to be the inferior rectal artery supplying the outer layers of the muscular wall in the area up to about three cm above the dentate line. We did not consider that these vessels were branches of the middle rectal artery since this artery is reported to supply the rectum above the levator ani muscle. We were unable to find any casted vessel that might be part of the middle rectal artery in any of the cadavers, although this possibility cannot be completely excluded. Since Araldite is generally considered to be a suitable agent for visualization of the small-sized vessels [10, 11], we would have expected it to show the middle rectal artery if that were present.

It has been suggested in the past that the arteries in the distal rectal submucosa are arranged in the classic 3, 7 and 11 o'clock positions. Others have indicated a more complicated picture of 1, 3, 5, 7, 8 and 11 o'clock [1, 12-14]. In the present study distribution patterns appeared to differ from these configurations since the course of the submucosa vessels and their length, diameter and number indicated that the arrangement is not constant. It is therefore questionable whether these typically positions are useful in clinical practice.

Hemorrhoidal artery ligation therapy (HAL/THD) is minimally invasive and produces little pain [7,12,14]. Its aim is to reduce the blood flow to the haemorrhoidal plexus by identifying the arterial branches by ultrasound Doppler probe and ligating them individually. In the light of the present study, it is likely that not all arteries are found and ligated despite good results being reported. This calls into question the precision of ultrasound Doppler identification. Besides artery ligation it may be that HAL also produces an anopexy effect caused by the placement of the sutures.

Conclusion

The distal rectum is supplied by the superior rectal artery. The arteries supplying the corpus cavernosum recti are not found in the locations stated in the literature.

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Figure legends

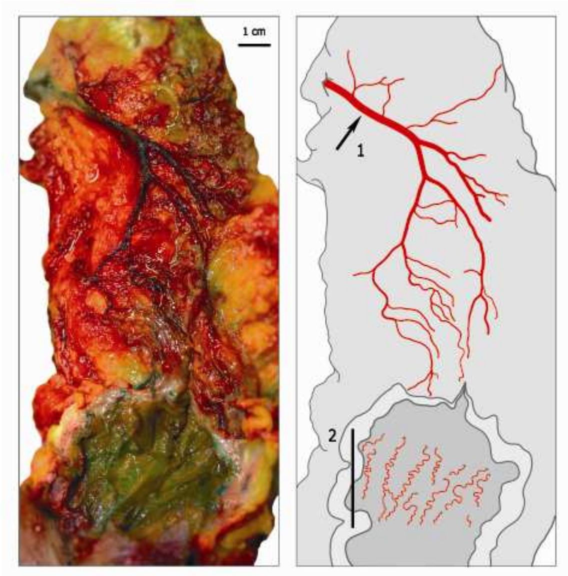
Figure 1. Posterior view of a non fixed specimen in which the connective tissue and fat have been removed for better visualization of the vessel casts. (1, superior rectal artery) (2, opened anal canal providing a view of the corpus cavernosum recti)

Figure 2. Araldite cast in a semitransparent specimen of the distal rectum showing the superior rectal artery (1) and opened anal canal providing a view of the corpus cavernosum recti (2).

Figure 3. Posterior view on the rectum showing the course of the superior rectal artery with a detailed picture of the corpus cavernosum recti.

Figure 4. Green casted vessels (1) emerging at the surface of the internal lining of the rectum continuing to the dentate line (2, between arrows).

Figure 5. Still frame of the reconstruction video showing a cross sectional cut with a vessel (arrow) penetrating through the bowel wall (BW). Lumen (L).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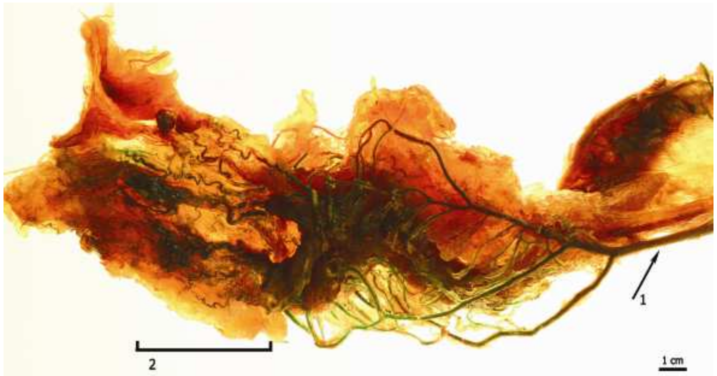
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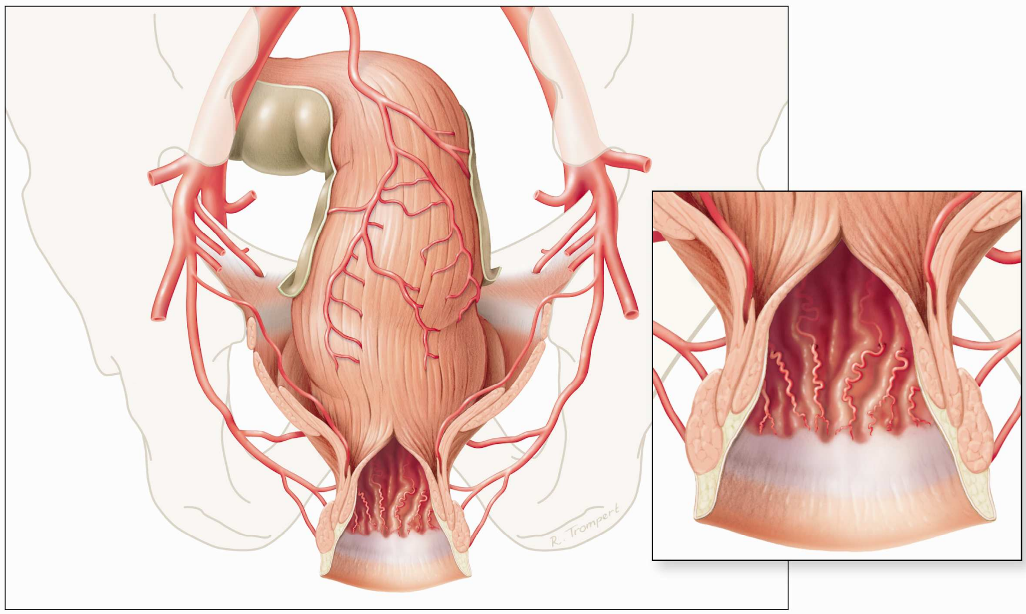
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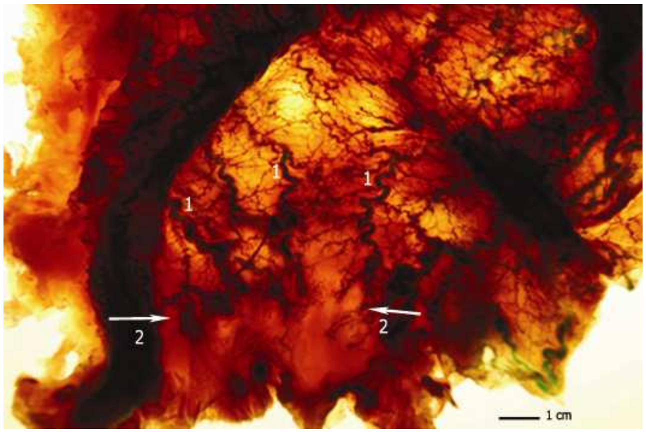
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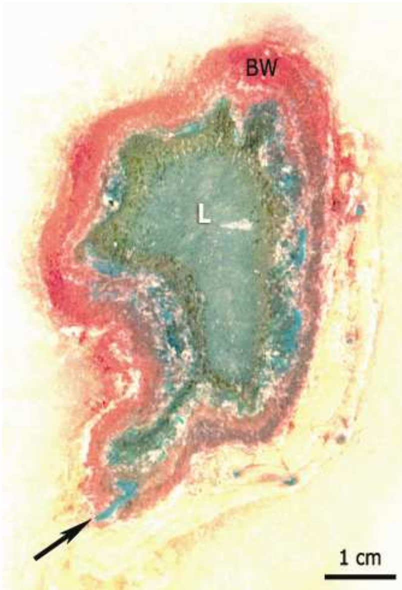
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