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**Arterial Anatomy of the Anterior Abdominal Wall:****Evidence-Based Safe Sites for Instrumentation based on Radiological Analysis of 100 Patients**

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**Abstract****Introduction**

Multiple medical interventions require percutaneous instrumentation of the anterior abdominal wall, all of which carry a potential for vascular trauma. We assessed the presence, position and size of the anterior abdominal wall superior and inferior (deep) epigastric arteries to determine the safest site with respect to vascular anatomy of the rectus sheath.

**Materials & Methods**

In a review of 100 arterial phase, contrast-enhanced abdominal computed tomography scans, anterior abdominal wall arteries were assessed bilaterally at three axial planes: transpyloric, umbilicus and anterior superior iliac spine (ASIS).

**Results**

The mean age of patients was 69.2 years (SD±15), with 62 male and 38 female. An artery was visible least frequently at the transpyloric plane (5%), compared to the umbilicus (72-79%) and ASIS (93-96%), on the left ( $\chi^2(4)=207.272$ ;  $p<0.001$ ) and right ( $\chi^2(4)=198.553$ ;  $p<0.001$ ), with a moderate strength association (Cramer's  $V=0.588$  (left) and  $0.575$  (right)). The arteries were most commonly observed within the rectus abdominis muscle at the level of the umbilicus and ASIS on both sides (62-68%). The inferior epigastric artery was observed to be larger in diameter, start more laterally, and move medially as it travelled superiorly.

**Discussion**

These data suggest that the safest site to instrument the rectus sheath, with respect to vascular anatomy, is at the transpyloric plane. This information on anatomical variation of the anterior abdominal wall vasculature may be of particular interest to anesthetists performing rectus sheath block and surgeons during laparoscopic port insertion.

**Key words:** Anatomical variation; epigastric artery; rectus sheath block; complications

## Introduction

Multiple medical interventions require percutaneous instrumentation of the anterior abdominal wall, such as laparoscopic surgery involving abdominopelvic organs, where ports are inserted through the abdominal wall to access the peritoneal cavity. Rectus sheath block (RSB) is another example; local anesthetic is deposited within the rectus sheath to provide sustained analgesia after midline laparotomy (Yarwood & Berrill, 2010; Rucklidge & Beattie, 2018).

Complications may occur following such procedures, including damage to the superior and inferior (deep) epigastric arteries that run within the anterior abdominal wall, which may result in rectus sheath haematoma or epigastric artery pseudoaneurysm (Yuen & Ng, 2004; Kawamura et al., 2006; Standring, 2008; Proccianti et al., 2009; Yarwood & Berrill, 2010; Ko et al., 2010; Splinter & Cook, 2012). The incidence of vascular injury during these techniques is unknown. As continuous RSB is seen as an alternative to epidural analgesia in patients on concomitant anti-platelet agents, anti-coagulation or those with coagulopathy (Rucklidge & Beattie, 2018), it is important to consider the potential for vascular trauma during this procedure.

Conventional anatomical descriptions of the course of the superior and inferior (deep) epigastric arteries discuss anatomical variation to a lesser degree (Standring, 2008; Sinnatamby, 2011). This is of particular relevance to anesthetists performing RSB, which involves needle insertion traversing the rectus abdominis muscle, to the posterior space of the rectus sheath. The optimal method of needle and catheter insertion is still not certain (Rucklidge & Beattie, 2018). Therefore, it is unclear whether recommended sites to perform RSB, often proximate to the umbilicus, are optimal in respect to the vascular anatomy of this region (Ferguson et al., 1996; Courreges et al., 1997; Yarwood & Berrill, 2010; New York School of Regional Anesthesia, 2013; Rucklidge & Beattie, 2018).

This study assessed the deep epigastric arterial anatomy of the anterior abdominal wall. The primary outcome was to determine the presence of the dominant artery, that was visible on computed tomography (CT), at three different planes that are used in clinical practice: the transpyloric plane (midway between the xiphisternum and umbilicus), the umbilicus and the anterior superior iliac spine (ASIS). If present, the secondary outcomes were to determine the topographical relationship between the artery, rectus abdominis muscle and rectus sheath, and assess its size. The principal aim was to determine, based on the above information, the safest site for needle and catheter insertion during RSB with respect to vascular trauma. Another aim was to provide more information in relation to the anatomical variability of the deep arteries in the anterior abdominal wall, which is of importance in order to avoid these vessels during instrumentation in the region (as is the case for port site insertion during laparoscopic surgery).

## Materials and Methods

Caldicott Guardian approval was obtained to undertake a retrospective review of abdominal CT scans from 01 January - 05 May 2015. Scans selected for review were intravenous contrast-enhanced CT scans acquired in the arterial phase, performed for patients with suspected intra-abdominal pathology. All CT scans were assessed by a radiologist: each was initially reviewed to determine whether it was suitable for inclusion in the study, based on the adequacy of arterial enhancement. Then the presence of the relevant artery(ies) was assessed bilaterally at three axial planes that are consistently identifiable on radiological assessment and used in clinical practice. These levels were: the transpyloric plane (midway between xiphisternum and umbilicus), the level of the umbilicus, and the level of the anterior superior iliac spine (ASIS) (see figure 1). Where found, the arterial relation to the rectus abdominis muscle and rectus sheath was determined: anterior, intra-rectus, posterior (between the rectus abdominis muscle and posterior layer of the rectus sheath), not visible, and other. Arterial diameter was measured three times: the shortest axial measurement was recorded to reduce the risk of measuring the diameter at an oblique angle and thus overestimating. Coronal images were assessed to determine in which sagittal division of the ipsilateral rectus abdominis muscle (medial, middle or lateral third, or other) the artery lay (Fig. 1).

**Figure 1. Axial and sagittal planes used for assessment of presence, position and size of superior and inferior (deep) deep epigastric arteries**

An independent researcher, not involved in data collection (to eliminate bias), conducted the statistical analysis that was performed in IBM SPSS® software version 24. A chi-square test was used to explore whether there was an association between the presence of the artery and the three different axial planes on the right and left side separately, with exact p values stated taking into account some of the low frequencies to prevent reporting of potentially artificially high values. Cramer's V was then used to assess the strength of association for statistically significant results.

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## Results

In total, 105 scans were reviewed, with five rejected for inclusion because of suboptimal image quality due to inadequate arterial enhancement. Consequently, 100 scans were reviewed and analyzed; 62 male and 38 female. The mean age of the patients was 69.2 years (SD±15), ranging from 25 to 91 years. Forty-eight scans were undertaken to assess an abdominal or thoracic aneurysm (or previous repair), 17 to assess potential intra-abdominal bleeding and seven to assess suspected aortic dissection. Twenty-eight were undertaken for a range of other indications (e.g. trauma).

The dominant artery of the anterior abdominal wall was identified at the transpyloric plane in 5% of cases bilaterally. Such an artery was identified in 79% and 72% at the level of the umbilicus on the left and right sides respectively. At the level of the ASIS, the artery was identified in 96% and 93%, on the left and right sides respectively. Cross-tabulation of frequencies highlighted this increasing trend in relation to the presence, and hence count, of arteries descending inferiorly on the anterior abdominal wall (see supplementary file). This association between the presence of arteries and the three different planes was noted to be significant on the left ( $\chi^2(4)=207.272$ ;  $p<0.001$ ) and right ( $\chi^2(4)=198.553$ ;  $p<0.001$ ) sides, and was of moderate strength (Cramer's  $V=0.588$  (left) and  $0.575$  (right)).

When an artery was present at the transpyloric plane, it lay in the middle third of the ipsilateral rectus abdominis muscle on both sides. This was also the most frequently observed position at the level of the umbilicus, with 54% on the left and 47% on the right. At the level of the ASIS, the artery was most commonly observed in the lateral third of the muscle; 63% on the left and 62% on the right.



At the transpyloric plane, an artery was observed within the rectus abdominis muscle in 4% on the left and 3% on the left. At the level of the umbilicus, an artery was observed within the muscle in 67% on the left and 62% on the right. Similarly, the main artery was observed within the muscle in 68% on the left and 64% on the right at the level of the ASIS (see table 1). At this level, the artery was also observed in the posterior rectus sheath in just under one third of cases (28% left, 29% right).

**Table 1. Position of the dominant artery (visible on CT) in relation to the rectus abdominis muscle within the rectus sheath**

The artery was found to be of a larger diameter inferiorly, arising from the inferior epigastric artery. At the transpyloric plane, the artery had a mean diameter of 1.1 mm (SD±0.183; min-max range=1-1.4) on the left and 1.1 mm (SD±0.154; min-max range=1-1.3) on the right. At the level of the umbilicus, the mean diameter was also 1.1 mm (SD±0.240; min-max range=1-2.3) on the left and 1.0 mm (SD±0.116; min-max range=1-1.7) on the right. At the level of the ASIS, the mean diameter was 1.3 mm (SD=0.345; min-max range=1-2.4) on the left and 1.3 mm (SD±0.344; min-max range=1-2.50) on the right (see supplementary file).

## Discussion

We have sought to determine at which readily-identifiable anatomical location(s), where RSB may be performed, an artery is encountered with the lowest frequency (as seen on CT). The anatomical variation of the vasculature of the anterior abdominal wall has not previously been described and is potentially useful to regional anesthetists and surgeons performing laparoscopic surgery in the abdominopelvic cavity.

The superior and inferior (deep) epigastric arteries supply arterial blood to the anterior abdominal wall. Anatomical texts describe the superior epigastric artery passing into the abdominal cavity between the xiphisternal and costal slips of the diaphragm, lying within the rectus sheath and behind the muscle (Standring, 2008; Sinnatamby, 2011; Rucklidge & Beattie, 2018). The inferior epigastric artery passes up from the external iliac artery and pierces the transversalis fascia to lie on the posterior surface of the muscle, entering the rectus sheath anterior to the arcuate line (Standring, 2008; Sinnatamby, 2011; Rucklidge & Beattie, 2018). The arteries are said to anastomose within the rectus sheath, posterior to the rectus abdominis, at a variable height above the umbilicus (Standring, 2008; Sinnatamby, 2011; Rucklidge & Beattie, 2018). Descriptions do not generally include discussion of anatomical variation.

In 100 CT scans, the deep epigastric arteries were found to be smaller superiorly and start more medially in the abdomen relative to the rectus abdominis muscle. The inferior epigastric arteries started more laterally and, as described elsewhere (Standring, 2008), were of larger calibre (see figure 2). The artery lay most commonly within the rectus abdominis muscle, rather than in the posterior rectus sheath as is often described (Standring, 2008; Sinnatamby, 2011; Rucklidge & Beattie, 2018).

**Figure 2. A typical scan showing the larger inferior epigastric artery, with the superior epigastric artery ending early in its course down the abdominal wall**

It can also be seen from these data that the arteries are not always present, which may be assumed by readers but is often not stated. In addition, they are of unequal size and vary in their position in relation to the rectus muscle and sheath. Of the readily-identifiable anatomical landmarks which may be used to guide needle or catheter insertion during RSB, an artery (visible on CT) was present least frequently at the level of the transpyloric plane (midpoint between the xiphisternum and umbilicus). Further, the arteries were also at their smallest calibre at this site. When attempting to traverse the rectus abdominis muscle with a needle, in order to deposit local anesthetic in the posterior sheath, anesthetists should be wary that the vessel may be encountered within the rectus musculature (rather than in the posterior space of the sheath as is typically described).

The findings of the current study provide data to inform safe practice when deciding on the puncture site least likely to result in arterial injury during needle insertion, thus mitigating the risk of vascular injury and rectus sheath haematoma. Rectus sheath block has often been described in the peri-umbilical region during pediatric practice, using a blind technique, relying on tactile feedback to guide local anesthetic injection (Ferguson et al., 1996; Courreges et al., 1997). Ultrasound is now frequently used when performing RSB and has been demonstrated to improve the accuracy of local anesthetic deposition (Dolan et al., 2009). Knowledge of the anatomy and its variation may aid identification of the vessels on ultrasound at specific points within the anterior abdominal wall, however the vessels are not always readily visible on ultrasound. Furthermore, RSB is sometimes performed by surgeons under direct vision at the end of an operation, which also risks arterial injury as the vessels are not seen. This is another situation where knowledge of the underlying anatomy is of paramount importance. Plastic and reconstructive breast surgery rely on the presence of these vessels for deep inferior epigastric perforator (DIEP) flap breast

reconstruction after mastectomy (Molina et al., 2012). Therefore knowledge of their structure is of importance in this field, as it also is for general and gynecological surgeons to avoid vascular trauma during port site insertion surgery, or other clinicians during invasive procedures of the anterior abdominal wall (Procacciante et al., 2009; Ko et al., 2010; Splinter & Cook, 2012).

The authors acknowledge that the data presented arise from a relatively elderly population (mean age 69.2 years) and that caution should be applied when extrapolating these data to patients, particularly children. However, in adult practice, this is the age cohort of patients in whom RSB is routinely considered. We were unable to gather data on patient ethnicity, which is another consideration regarding the generalizability of these findings. A single radiologist assessed all CT scans, which provided consistency, however it is possible that the accuracy of the data might be improved if the scans were analyzed by multiple radiologists. These CT scans were most frequently performed in patients with underlying or suspected vascular pathology which may affect vessel calibre (although this is less likely to affect the course of the vessel). There was no available information regarding previous abdominal surgery in the study group. For example, the anatomy would clearly be distorted in a female patient having previously undergone a DIEP flap breast reconstruction.

### **Conclusions**

This study provides a description of the anatomical variation of the arteries of the anterior abdominal wall. At the present time, we are not aware of any previous comparable description. The inferior epigastric artery is of larger diameter and is more frequently encountered at or below the level of the umbilicus. It is most often intramuscular but some lie in the posterior rectus sheath. A dominant artery (visible on CT) is least likely to be encountered at the transpyloric plane (the midpoint between the xiphisternum and umbilicus). It is hoped that this knowledge, combined with

prudent use of ultrasound guidance, may help to minimize the risk of inadvertent arterial trauma during RSB and other instrumentation in this region.

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**Table 1. Position of the dominant artery (visible on CT) in relation to the rectus abdominis muscle within the rectus sheath**

	Left (n=100)					Right (n=100)				
	Intra-rectus	Posterior to rectus	Anterior to rectus	Not seen	Other	Intra-rectus	Posterior to rectus	Anterior to rectus	Not seen	Other
<b>Transpyloric</b>	4%	0%	1%	93%	2%	3%	2%	0%	94%	1%
<b>Umbilicus</b>	67%	11%	1%	20%	1%	62%	6%	4%	26%	2%
<b>ASIS</b>	68%	28%	0%	0%	4%	64%	29%	0%	0%	7%



**Sagittal Divisions of Rectus Abdominis (Into Thirds)**



