Acta Scientific MEDICAL SCIENCES (ISSN: 2582-0931)

Volume 10 Issue 1 January 2026

Research Article

Study of Anatomical Variations in the Umbilic-Aortic Bifurcation Distance: Application to Surgery

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DOI: 10.31080/ASMS.2026.10.2196

Received: November 09, 2025

Published: December 31, 2025

Abstract

Introduction: The anatomical location of the bifurcation relative to the umbilicus is an important landmark in laparoscopy. Knowledge of it is also essential for safe surgery. The aim of our work was to propose a Senegalese database on the umbilicus-aortic bifurcation distance that could improve the prevention of certain surgical accidents.

Patients and Methods: This is a retrospective, descriptive study that included all patients who received an abdominal CT scan with contrast injection, coronal reconstruction, and axial slices. Epidemiological factors, the position of the bifurcation relative to the umbilicus, the distance between the umbilicus and the bifurcation, and associated factors were studied. Pearson's chi-squared test and the correlation coefficient were used to determine statistical relationships.

Results: The mean age was 46.5 years, with a range of 4 to 80 years, and a sex ratio of 0.5 in a sample of 102 patients. The mean BMI was 23.7 kg/m^2. The aortic bifurcation was predominantly located above the umbilicus in 59.8% of cases. We did not find a link between the position of the bifurcation relative to the umbilicus with sex ($p = 0.052$) or BMI ($p = 0.172$). However, it should be noted that the bifurcation is often located below the umbilicus in female subjects (81.3%). However, age (over 40 years) was linked to the location of the bifurcation ($p = 0.032$). We found no correlation between the umbilico-aortic distance and age ($p = 0.133$) or BMI ($p = 0.136$).

Conclusion: Knowledge of anatomical variations in the distance between the umbilicus and the aortic bifurcation is necessary in laparoscopy for the prevention of vascular lesions.

Keywords: Umbilicus; Aortic bifurcation; Location

Introduction

The umbilicus is the skin depression that results from the healing process following the detachment of the umbilical cord in a newborn [16]. It corresponds to the central region of the abdomen, which can be the site of numerous pathologies, notably umbilical hernia [22]. It is an important landmark in the surgical approach to the abdomen, both in open surgery and laparoscopy. However, its relationship with variations in the aortic bifurcation (lumbar prominence at L4 or L4-L5 disc) raises the issue of aortic vascular injury. These injuries are rare, occurring in 19.3% of cases [9], but can be life-threatening. They are located at the bifurcation and often occur during the insertion of the optical trocar at the umbilical level during surgery [9]. They can also cause gas embolism during pneumoperitoneum insufflation, which can be fatal [18]. Despite the use of less traumatic instruments, the incidence of accidents has not decreased [15].

This proves that prevention must involve anatomical knowledge of the position of the umbilicus in relation to the aortic bifurcation. This position presents a great deal of inter-individual variability due to several factors, including obesity and the subject's phenotype [2]. In Senegal, the literature provides very little data on the umbilicus-aortic bifurcation distance and its anatomical variations; the same is true of anatomical works. This observation has sparked interest in studying the anatomical variations in the distance between the aortic bifurcation and the umbilicus, as well as the impact of sociodemographic data on these variations in the Senegalese population. Understanding these variations is essential for preventing certain surgical complications. The aim of our work was to propose a Senegalese database on the umbilicus-aortic bifurcation distance that could improve the prevention of certain surgical accidents.

Materials and Methods

This is a prospective, descriptive and analytical study carried out in the medical imaging department of the Dalal Jamm National Hospital Center (CHNDJ) in Guédiawaye (Dakar). It included all patients who underwent abdominopelvic computed tomography with contrast injection in the arterial phase and with coronal and sagittal reconstruction images. Identification of the umbilicus and the aortoiliac bifurcation was mandatory. Patients with: an aortic aneurysm; a history of extensive surgical resection; an abdominal mass greater than 8 cm; or factors or processes preventing localization of the aortic bifurcation and/or the umbilicus were excluded from the study. All distances were expressed in millimeters. If the aortic bifurcation was located below the umbilicus, the distance was considered a negative value. If the aortic bifurcation was located above the umbilicus, the distance was considered a positive value. The data was collected via a questionnaire created on Google Form and processed using Microsoft Excel and SPSS software.

The data were expressed as means or medians, extremes and frequencies depending on the type of variable. The confidence interval (CI) was 95%.

Pearson's chi-squared test was used to investigate correlations between qualitative variables. The correlation coefficient was used between quantitative variables. A threshold of 5% was defined, and the odds ratio was used to estimate the strength of the association. We used a Siemens Somatom go-top 64-slice 128-slice multi-detector scanner which could perform thin native volumetric slices of 0.6 mm with three-dimensional reconstructions in the transverse, coronal and sagittal planes. Patients were positioned in the supine position. Vascular access was ideally achieved via venous access using a 16-gauge catheter. Acquisitions were performed with thin slices of 0.6 mm after injection of iodinated contrast medium concentrated at 300 mg/l at a rate of 2 ml/kg at a flow rate of 2 to 3.5 ml/s followed by a bolus of physiological saline using an automatic injector. The acquisition protocol followed the standard protocol with the acquisition of non-contrast slices, an arterial phase, a venous phase and a delayed phase. In our study, only arterial time images (25 to 30 seconds) were useful for data collection. Finally, we performed a reading on a dedicated console (Syngo-via) in MPR mode, with maximum intensity projection (MIP), minimum intensity projection (MinIP), and volumetric rendering (VRT). We first located the umbilicus on a sagittal section as shown in Figure 1. Next, on 2 adjacent reading windows, the aortic bifurcation was located on a coronal section as illustrated by Figure 2. Then, using the same figure, the umbilicus was located on a coronal or sagittal reconstruction in a second window. Two horizontal reference lines were drawn, one passing through the umbilicus and the other through the aortic-iliac bifurcation. The distance between these 2 marked lines was then measured in millimeters (mm). Finally, on a sagittal reconstruction, the thickness of the anterior abdominal fat was measured, expressed in millimeters and illustrated by Figure 3. All distances were expressed in millimeters.

Figure 1: Locating the umbilicus on a sagittal reconstruction.

1: Umbilicus

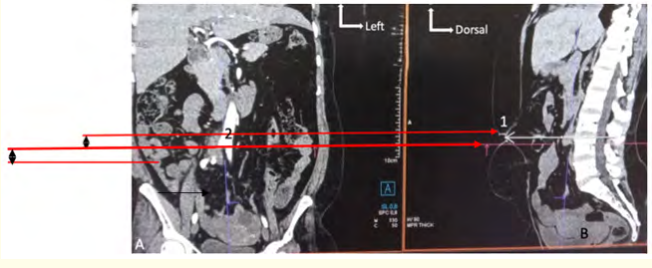

Figure 2: Calculating the umbilical-aortic distance.

1: Umbilicus 2: Aortic bifurcation

A: Identification of the aortic bifurcation on a coronal reconstruction.

B: Identification of the umbilical depression on a sagittal reconstruction.

Figure 3: Measurement of the thickness of the anterior abdominal wall.

1: Thickness of the fat in the anterior abdominal wall.

This allowed us to study the epidemiological (age, sex, body mass index), the indications for abdomino-pelvic CT scan (tumors, assessment of extent, emergencies…). Similarly, we were also interested in the situation of the bifurcation in relation to the umbilicus (above, below, or at the same level in relation to the distance between the umbilicus and the bifurcation, expressed in mm). It is positive if the bifurcation is below and negative when it is above. Finally, we measured the thickness of the anterior abdominal fat below the umbilicus and expressed it in millimeters (mm).

Results

We collected a total of 102 cases. The mean age was 46.5 years (95% CI: 43.3-49.6 years), with a range of 4 to 80 years, and a sex ratio of 0.5.

Body Mass Index (BMI) was assessed in 34.3%. The mean weight was 67.43 kg (95% CI: 62.7-72.6) with extremes of 36 kg and 98 kg. The mean height was 167.9 cm (95% CI: 164.7-170.9).

The mean BMI was 23.7 $kg.m^2$ across the entire study population (95% CI: 22.3 $kg.m^2$ - 25.3 $kg.m^2$) with extremes of 15 $kg.m^2$ and 34 $kg.m^2$. By sex, the mean BMI was 24.5 $kg.m^2$ in female subjects and 20.9 $kg.m^2$ in male subjects. Selon la répartition de l'IMC selon l'OMS, nous notions 42,9% de sujets qui étaient en surpoids et 37,1% qui avaient un IMC normal.

The assessment of the extent of digestive or extra-digestive tumors represented 36.3% of the indications, computed tomography was performed in the investigation of abdominal pain in 25 patients. Surgical history was reviewed in our patients. Only 7 patients (6.9%) had a history of abdominal surgery. None of these cases were exclusion criteria.

The aortic bifurcation was predominantly above the umbilicus (59 patients) followed by the position below (31 patients) and the remaining 10 patients had a position coinciding with the level of the umbilicus.

Regarding the distribution of subjects according to the location of the bifurcation relative to the umbilicus, we noted that the bifurcation is often located below the umbilicus in female subjects (81.3%). However, we did not find a statistically significant link between sex and the location of the bifurcation relative to the umbilicus ($p = 0.052$).

Furthermore, in patients over 40 years of age, the bifurcation tends to be above the umbilicus with a statistically significant link.

Similarly, we found no influence of BMI on the position of the aortic bifurcation (p = 0.172). Indeed, obesity did not affect the position of the bifurcation relative to the umbilicus.

Regarding the distance between the umbilicus and the aortic bifurcation, the distance is between 78 mm above the umbilicus and -61 mm below the umbilicus with an average of 18.1 mm (95% CI 15.2 mm - 21.2 mm).

Regarding the position of the bifurcation relative to the umbilicus: the situation above the umbilicus was on average 20.4 mm, and below it was on average -19.4 mm with 19.1 mm in male subjects and 17.6 mm in female subjects.

We did not find a correlation between umbilico-aortic distance and age (p = 0.133) or BMI (p = 0.136).

Anterior abdominal fat thickness was assessed in all patients, with a mean of 20.36 mm and a range of 0 to 80 mm. It was 24.3 mm in female subjects and 12.2 mm in male subjects. We found no correlation between anterior abdominal fat thickness and the umbilico-aortic distance (p = 0.056).

Discussion

The study of the situation of the aortic bifurcation in relation to the umbilicus involves several methods, including radiological or laparoscopic [15,21,24,27].

In radiology, abdominopelvic computed tomography has been the most used. Coronal and/or sagittal reconstructions on 2 windows allow the levels of the umbilicus and the aortic bifurcation to be identified and thus the distance expressed in millimeters [15,21].

However, other authors have used laparoscopy. This method requires general anesthesia and the insertion of at least two trocars. The aortic bifurcation is then visually located using forceps. Thus the umbilico-aortic distance is measured. This method also allows the angle between the umbilicus and the bifurcation to be determined from the horizontal [24]. However, it remains the most invasive and requires significant logistics related to the use of laparoscopy, unlike the CT scan method. Similarly, no difference in the quality of the results was found based on the method used. Thus, we judged that the reading method, particularly using computed tomography, appears reliable and less invasive for measuring the distance between the umbilicus and the aortic bifurcation. Some authors have also used ultrasound to determine the thickness of the subcutaneous fat [27]. In our study, this thickness was measured simultaneously with computed tomography, which saved us from repeating additional examinations. Regarding the position of the bifurcation relative to the umbilicus, the results of our study, as reported by many other authors, show that the position of the aortic bifurcation relative to the umbilicus is highly variable [14,15,27]. The proximity of the aortic bifurcation to the umbilicus has been clearly identified as a risk factor for injury during laparoscopy [7]. Its position relative to the umbilicus is variable and depends on several factors, of which age, sex and obesity have been the most studied [15,21].

Traditionally, many authors agree that in obese female subjects, the aortic bifurcation is found above the umbilicus [10,12]. Conversely, a retrospective Korean study using the radiological method found that the bifurcation is below the umbilicus in obese female subjects [15]. This proves once again the variability in the position of the bifurcation depending on the individual.

Our study is unique in that it includes subjects of both sexes. Some studies are mostly carried out in gynecology departments, which then only include female subjects [15,21,24]. However, we found no link between the position of the bifurcation and sex (p = 0.052). Nevertheless, we noted that in female subjects, the bifurcation was often below the umbilicus (81.3%).

BMI is the factor most often correlated with the position of the umbilicus. We found no statistically significant link between BMI and the position of the bifurcation in our study (p = 0.172). The small sample size and the limited information available on our patients' BMI are among the limitations of our study.

Age has also been implicated in influencing the position of the bifurcation. In our study, we found a positive correlation between advanced age (over 40 years) and the position of the bifurcation (p = 0.032). In the literature, age is more correlated with the distance between the umbilicus and the bifurcation than with the actual position. Physiologically, the loss of skin elasticity due to age could influence the position of the umbilicus; this is more pronounced in female subjects [15]. Regarding the distance between the umbilicus and the aortic bifurcation, most previous studies involved female subjects [14,15,24]. In our study, this distance was between 78 mm

above the umbilicus and 61 mm below, with an average of 18.1 mm. This is proportional to the data in the literature, with an average of around 20 mm in mixed series [4]. We had an average of 19.1 mm in our male subjects and 17.1 mm in our female subjects, but this difference was not statistically significant (p = 0.133). Apart from sex, many other factors can influence the length of this distance [4, 15, 24], hence our interest in age, which shows highly variable results depending on the research team. The Korean study established that age is negatively correlated with the umbilico-aortic distance. The following equation was deduced from their work and allows this distance to be determined as a function of the patient's age: vertical distance = 8.9 - 0.3 × (age) [15]. However, its applications remain limited given the numerous variations in results from one study to another. This is all the more true since other authors have not found a link between age and distance [4]. In our series, we found no correlation between age and umbilico-aortic distance.

In the same vein, the Body Mass Index (BMI) indicates that the aortic bifurcation is often above the umbilicus in obese subjects. Regarding distance, we find no correlation with BMI and a reduction in distance with obesity [15]. Other results reveal a positive correlation, again in linear regression [21], whereas Nezhat's study [24], like our series, found no statistically significant link between this distance and BMI. This shows that the position of the aortic bifurcation relative to the umbilicus is generally dependent on the phenotype [8,20].

Other factors such as subcutaneous fat did not have a statistical link with umbilico-aortic distance. Some studies have established this correlation, but only in subjects over 65 years of age [4]. This age is quite specific in English studies as it represents the age of diagnosis of abdominal aortic aneurysms. Conversely, the patient's position during open surgery, and especially during laparoscopy, leads to changes in patient position. These changes often result in anatomical modifications, particularly in the position of the aorta relative to the umbilicus. In the supine position (0°), the aortic bifurcation was located below the umbilicus in only 11% of patients, compared to 33% in the Trendelenburg position. This difference was statistically significant for the total study population. However, these variations are not statistically significant [24]. Similarly, medical history (small bowel, colonic, etc.) and predisposing factors (presence of abdominal masses, aortic aneurysms) can influence the position of the umbilicus relative to the bifurcation. Therefore, like many authors, we decided to exclude subjects with these factors that could lead to discordant results.

This difference was statistically significant for the total study population. However, these variations are not statistically significant [24]. Similarly, medical history (small bowel, colonic, etc.) and predisposing factors (presence of abdominal masses, aortic aneurysms) can influence the position of the umbilicus relative to the bifurcation. Therefore, like many authors, we decided to exclude subjects with these factors that could lead to discordant results. Indeed, the laparoscopic approach via open or Veress needle remains a dangerous procedure from which vascular lesions can result, which in most cases affect the aortic bifurcation [17,25]. The authors agree that knowledge of the situation and the distance of the bifurcation from the umbilicus is an important tool in the prevention of these lesions [21]. This is especially true since the insertion angle of the Veress needle must be adjusted according to these physical data [7]. In practice, it is recommended to insert the Veress needle or the first trocar according to the patient's weight: less than 45 degrees in patients with a normal BMI, between 45 and 90 degrees in overweight patients, and more than 90 degrees in obese patients [14,15]. However, these recommendations could not be the subject of consensus given the numerous variations in position and report, but also because these studies only concerned female subjects.

Conclusion

In light of our results, knowledge of our anatomical data would help in the prediction of aortic lesions during open laparoscopy or Veress needle puncture. We noted that the bifurcation was located below the umbilicus in more than half of the cases, and this was even more pronounced in female subjects. Therefore, we suggest orienting the umbilical trocar upwards to better avoid this bifurcation. This is especially true since laparoscopy is more commonly used in female subjects due to the aesthetic advantage. However, a larger, multicenter study, using different measurement methods and specifically focusing on patients with an indication for laparoscopy, would allow for better adoption of these results into local recommendations.

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