„OVIDIUS" UNIVERSITY CONSTANŢA
DOCTORAL SCIENCE OF THE FACULTY OF MEDICINE

MORPHOLOGICAL ASPECTS OF THE INFERIOR VENA CAVA

SUMMARY OF THE DOCTORAL THESIS

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Contents

INTRODUCTION

The inferior vena cava system is the biggest venous collector of the human body, having also the most complex embryological development, each topographical segment having its origin in different embryo fetal veins. Due to this the variants and the anomalies of the inferior vena cava system are numerous, and on the other side the affections which it is a part of, are very many, this needing a better knowing of its embryological development and of its normal anatomy.

The numerous studies done on the morphology of the inferior vena cava show different sides of this vascular system: the bondage between the diameters of the inferior vena cava and the central venous pressure, the fact that the malformations of the inferior vena cava and the deep venous thrombosis can be accompanied by malformations and thrombosis also at the level of the portal vein and at the level of the mesenteric venous system, as well as the level of the end of the renal, gonadale, lumbar, and hepatic veins in the cava, the fact that the anatomy of the retrohepatic segment of the inferior vena cava determin the end of the hepatic veins, the bondage between the inferior vena cava and the renal veins, the existence of some venal shunts that are of most interest to the inferior vena cava, inferior mesenteric and gonadal veins etc.

The personal results have been capitalized by publishing two articles in extenso in The functional and clinical, macro and microscopic Anatomy Magazine and the Anthropology Magazine in 2016 and 2017, by presenting two papers at the National Anatomy Congress in Galati in 2016, published in the summary volume, with the help of a poster paper presented at the "98^{e} Congres de l'Association des Morphologistes et 21 ^{es}journee du CHEC" which took place in Toulouse in 2016, another paper presented at the National Congress of Anatomy in Iasi in 2017 and another one presented poster at the "98^{e} Congres de l'Association des Morphologistes et 21 ^{es}journee du CHEC" which took place in Reims in 2017.

MATERIAL AND WORK METHODS

My study on the morphology of the inferior vena cava has been done only on cavographies executed on a tomography computer GE LightSpeed VCT 64 Slice CT and on a tomography computer GE LightSpeed 16 Slice CT, two devices owned by the "SF. Andrei" Clinical Hospital in Constanta. Only the cavographies that have been done on subjects who did not present a pathology that interested the inferior vena cava, have been selected, thus being able to analyse the normal morphological characteristics of the vena cava inferior system. The obtained results have been classified according to their values and gender, being represented by a suggestive graphic, and in the discussion section the comparison with the literature being done with the help of tables.

RESULTS

THE FORMATION OF THE INFERIOR VENA CAVA

The level of formation of the inferior vena cava in relation to the spinal cord, has been studied on a number of 34 cases, 12 being of male gender and 22 of female gender. The formation of the inferior vena cava took place in the interval between the L3- L4 disc and the intervertebral L5- S1.

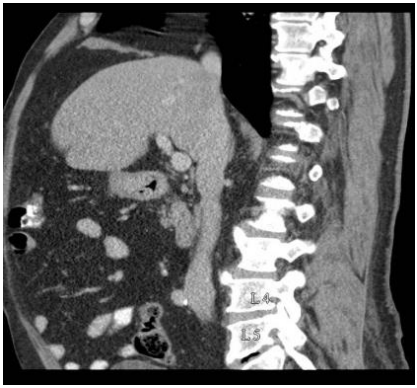


Fig.8. The formation of the inferior vena cava at the level of the L3 – L4 disc (male gender)

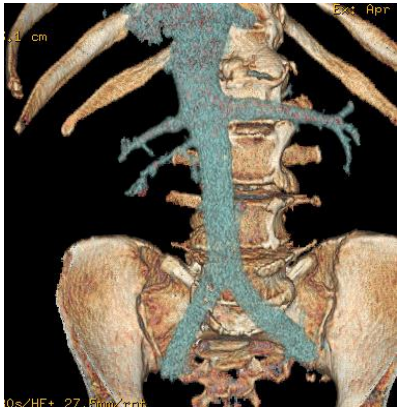
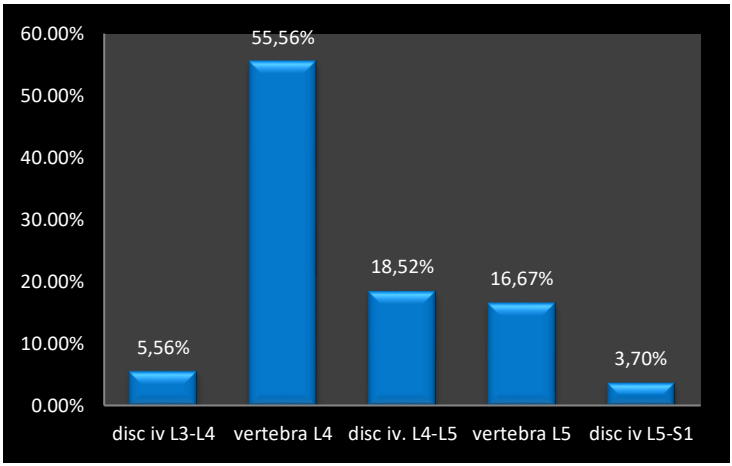


Fig.9. The formation of the inferior vena cava at the level of the middle antero- lateral right part of the L4 vertebra.



Graphic No.1 The level of formation of the inferior vena cava in relation to the spinal cord.

The formation of the inferior vena cava has been studied also in relation to the end of the aorta on a number of 72 cases: in 90.28% of the cases, the vena cava has formed inferior to the level of the end of the abdominal aorta, but only by male gender, in 8,33% of the total cases the formation of the vena cava has been situated at the same level with the end of the abdominal aorta, and in only one case by the male gender (1,39% of the total cases) the vena cava has formed above the terminal ramification of the aorta.

Fig.13 The inferior vena cava formed at the same level with the end of the abdominal aorta (male gender).

For ***the interiliac angle*** has been found a value between 51, 0 – 74,70 º, by the *female gender* having a value between 55,2- 84, 20º, by the *male gender* between 51,0-74,7º.

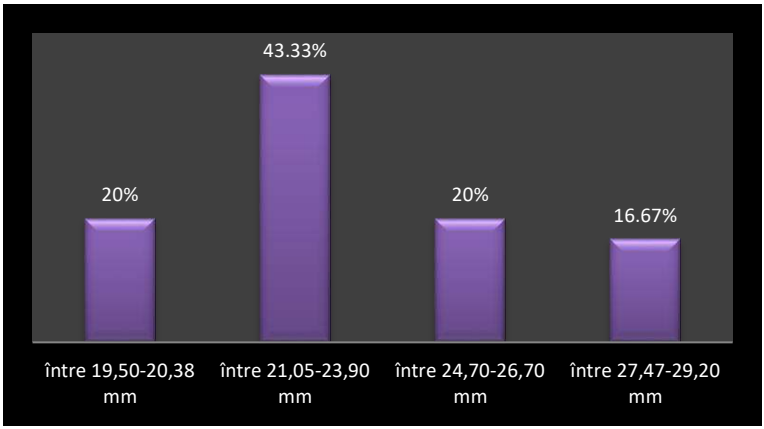
Fig. 18. The interiliac angle of 51,7º (male gender).


Fig.19 The right cavoiliac angle of 153,7º (female gender).

For ***the right cavoliac angle*** has been found a value between 137,7-169,2º by the *female gender*, and by the *male gender* between 146,1-162,1º.

The left cavoiliac angle has been found with a value between 116,3-163,1º, by the *female gender* having between 125,1-149,7º, by the *male gender* between 124,1 -163,1º, and also by the male gender between 12,4 -22, 4 mm

The external diameter of the inferior vena cava above its formation has been found between 19,02 -29,2 mm, by the *female gender* having a value of 19,02 -28,33 mm, and by the *male gender* between 21,05 -29,20 mm. By the *female gender* between 15,2-20,6 mm.



Graphic N0.7. The external diameter of the inferior vena cava above its formation.

Fig.24 The inferior vena cava has above its formation a external diameter of 21, 05 mm. The left renal vein has a diameter of 16,02 mm, and the right renal vein of 10,90 mm (by the male gender).

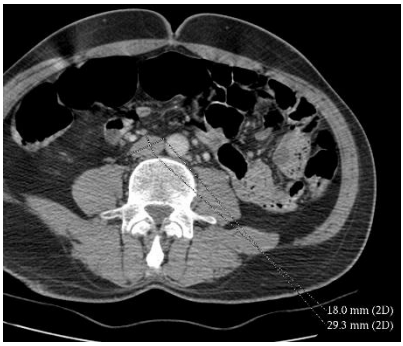


Fig.26 At the endovascular level, the inferior vena cava above its formation has a vertical diameter of 18,0 mm, and a horizontal diameter of 29,3 mm, the horizontal diameter being 11,3 mm longer (by the male gender).

The vertical endovascular diameter of the inferior vena cava at the level of its formation had a value between 12,40-17,93 mm, by the *female gender* has been between 15,2 -20,6 mm, and by the *male gender* between 12,4 -22,4 mm.

The horizontal endovascular diameter of the inferior vena cava at the level of its formation has been found between 17,70-33,0 mm, by the *female gender* between 18,6 -25,9 mm, and by the *male gender* between 17,7 -33,0 mm.

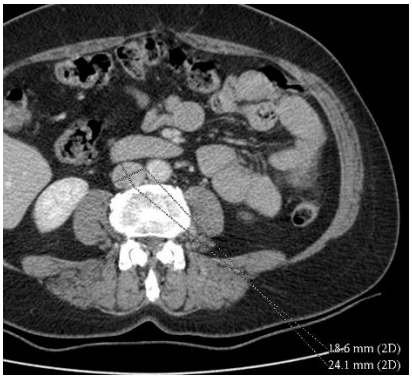


Fig.27 At the endovascular level, the inferior vena cava above its formation has a horizontal diameter of 24,1 mm, and a vertical diameter of 18,6mm, the horizontal diameter being 5,5 mm longer (by the female gender).

COMPARISON BETWEEN THE DIAMETER OF THE COMMON ILIAC VEINS RIGHT AND LEFT HAVING A DIAMETER AT THE ORIGIN OF THE INFERIOR VENA CAVA

- the diameter of the common right iliac vein represented between 51,31 -74,55 % of the diameter of the inferior vena cava at its formation level, and the diameter of the common left iliac vein represented between 31,86-64% of the diameter of the inferior vena cava at the level of its formation.

The diameter of the inferior vena cava under the level of the right renal vein termination in the inferior vena cava has found between 17,6-28,70 mm in the *female gender*, ranging from 18,09-28,08 mm, and in *male gender* between 17,60-28,70 mm.

The external diameter of the inferior vena cava at the level of infrarenal left has been measured on a number of 38 cases, 18 of *female gender* (47, 37 % has been found between 18,54-30,67 mm), by the *female gender* being between 18, 54 – 29, 93 mm, and by the *male gender* between 23,0- 30,67 mm.

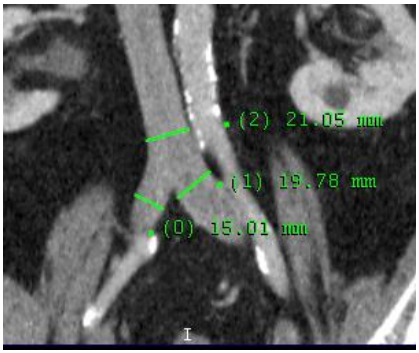


Fig. 38. The diameter of the right common iliac vein (15,01 mm) represents to 71,30% of the diameter of the inferior vena cava above its formation and the diameter of the left common iliac vein (19,78 mm) represents 93,97% of the inferior vena cava diameter above his level of its formation (male gender).

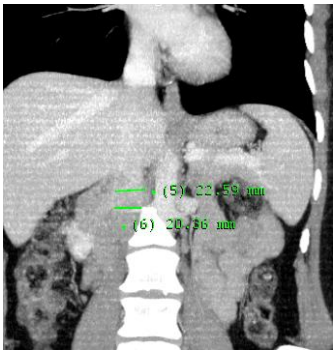


Fig. 41. The diameter of the inferior vena cava at right infrarenal is 20,36 mm, and the right suprarenal of 22,59 mm, the suprarenal diameter being 2,23 mm higher (female gender).

Fig.44 The diameter of the inferior vena cava infrarenal left is of 24,68 mm, and suprarenal left of 28,72 mm, the suprarenal diameter being 4,04 mm higher (by the male gender).

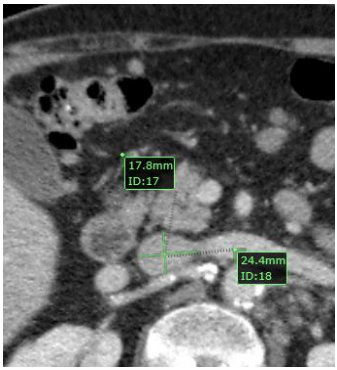


Fig. 51. The vertical cav endovascular diameter at the infrarenal level is of 17,8 mm, and the horizontal (24,4 mm) is 6,6 mm higher (by the male gender).

The vertical endovascular diameter of the inferior vena cava at the infrarenal level has been found between 14,40-21,20

mm, by the *female gender* being between 14,4-21,2 mm, and by the *male gender* between 15,90- 20,80 mm.

The endovascular horizontal diameter of the inferior vena cava at infrarenal level had a value between 19,41 mm-27,90 mm, by the *female gender* being between 19,41-27,90 mm, and by the *male gender* between 21,3- 26,40 mm.

Fig.52 The cav endovascular horizontal diameter at the infrarenal level is of 25,1 mm, and the vertical (20,3 mm) is 4,8 mm shorter (by the female gender).

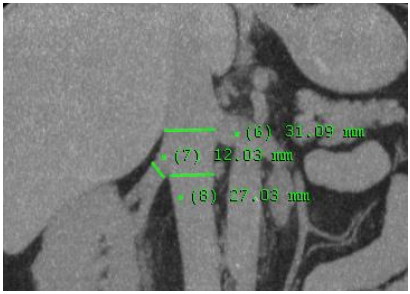


Fig. 55 The diameter of the inferior vena cava at the suprarenal right level (31,09 mm) is 4,06 mm higher, the infrarenal diameter (27,03 mm) on the same side (by the male gender).

The *diameter of the vena cava at suprarenal right level* has been found between 19,81-31,90 mm, by the *female gender* between 19,81- 31,34 mm, and by the *male gender* 21,30-31,90 mm.

The diameter of the inferior vena cava cranial to the end of the left renal vein has been found between 21,40 -33,80 mm, by the *female gender* between 21,40-31,36 mm, and by the *male gender* between 23,80-33,80 mm.

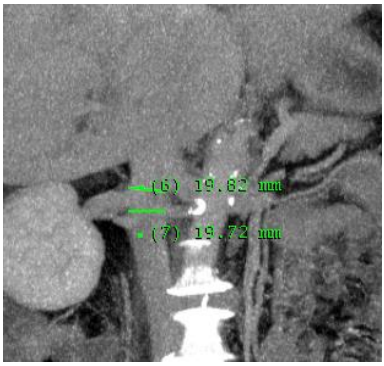


Fig. 56 The diameter of the inferior vena cava at the level of suprarenal right (19,82 mm) is longer than the right infrarenal diameter (19,72 mm) with 0,10 mm (by the male gender).

The exterior diameter of the inferior vena cava at infrahepatic level has been found between 18,80- 33,40 mm, by the *female gender* between 18,80-30,51 mm, by the *male gender* between 21,50-33,40 mm.

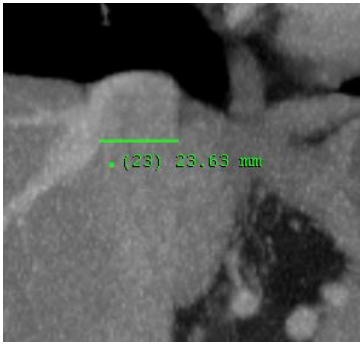


Fig. 65 The external diameter of the inferior vena cava at the infrahepatic level is of 23,69 mm (by the female gender).

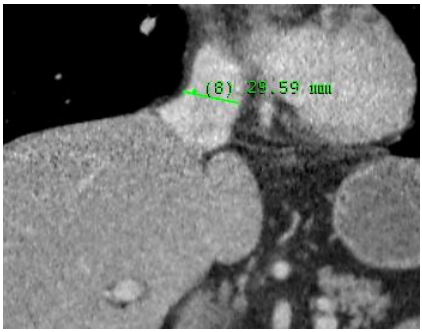


Fig. 68. The external diameter of the inferior vena cava at the suprahepatic level is 29,59 mm (by the male gender).

The external diameter of the inferior vena cava above the termination of the hepatic veins in the cava vein has been found between 20,46-37,0 mm, by the *female gender* between 23,50-24,18 mm, and and by the *male gender* between 20,46-37,0 mm.

The endovascular vertical diameter inferior cav at the infrahepatic level has been found between 17,70-19,70 mm, by the *female gender* between 17,7-30,1 mm, and by the *male gender* between 18,50-19,70 mm.

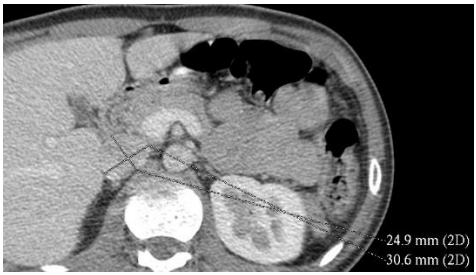


Fig. 71 The endovascular vertical diameter of the inferior vena cava at the infrahepatic level is of 24,90 mm, and the horizontal diameter (30,60 mm) being 5,70 mm longer (by the female gender).

The endovascular vertical diameter inferior cav at infrahepatic level has been found between 22,10-39,30 mm, by the *female gender* between 23,17-36,30 mm, and by the *male gender* between 22,10-33,70 mm.

Fig. 74 The horizontal endovascular diameter of the inferior vena cava at the infrahepatic level is of 32,30 mm, and the vertical diameter of 27,0 mm, the horizontal diameter being 5,30 mm higher (by the male gender*).*

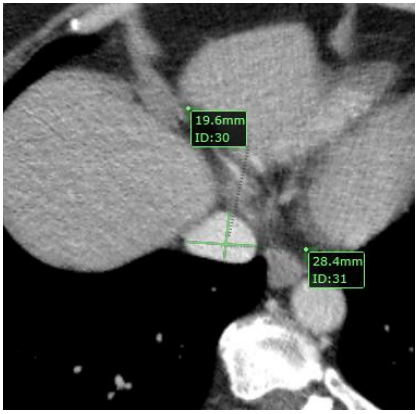


Fig. 75 The vertical endovascular diameter of the inferior vena cava at suprahepatic level is of 19,60 mm, the horizontal diameter (28,40 mm) being 8,80 mm higher (by the female gender).

The vertical endovascular diameter cav inferior at the suprahepatic level has been found between 16,60-33,80 mm, by the *female gender* being between 19,60-33,80 mm, and by the *male gender* between 16,60- 24,96 mm.

The horizontal endovascular diameter inferior cav at the suprahepatic level has been found between 20,80-39,40 mm, by the *female gender* between 20,80- 34,39 mm, and by the *male gender* 24,0 -39,40 mm.

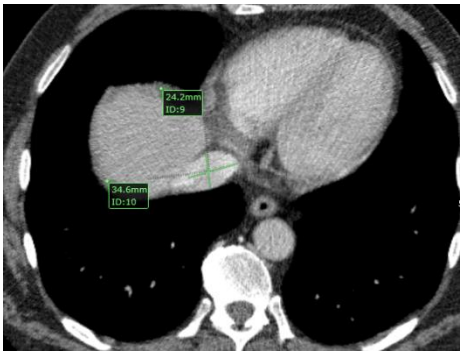


Fig. 78 The horizontal endovascular diameter of the inferior vena cava at the suprahepatic level is of 40,60 mm, and the vertical one of 24,2 mm (by the male gender).

Fig. 85. The total length of the inferior vena cava is of 232,70 mm (by the female gender).

The total length of the inferior vena cava, from its formation to its return to the right atrium has been measured on 58 cases, had 187,1-294,0 mm, by the *female gender* having between 187,10 -262,2 mm, and by the *male gender* between 215,40 -294,40 mm.

The length of the inferior vena cava from its formation to its return to the right renal vein was between 78,5-135,0 mm, by the *female gender* between 78,50 -106,80 mm, and by the *male gender* between 90,40-135,0 mm.

The length of the inferior vena cava from its formation to its return to the left renal vein has been found between 92,0-119,0 mm, by the *female gender* between 92,0 -95,0 mm, and by the *male gender* between 95,80-119,0 mm.

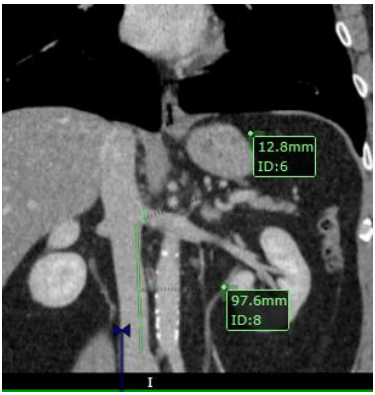


Fig. 90. The length of the inferior vena cava from its formation to the return to the left renal vein is of 97,60 mm. The diameter of the left renal vein is of 12,8 mm (by the male gender).

Fig. 91 The length of the inferior vena cava from its formation to to its return to the right hepatic vein is of 211,9 mm, and its length from its formation to its end is of 237,10 mm (by the female gender).

The length of the inferior vena cava from its formation to opening of the hepatic veins in it has been found between 167,70-263,70 mm, by the *female gender* between 167,70 -247,50 mm.

The length of the inferior vena cava from the right hepatic vein to the end of the vena cava in the right atrium has been found between 8,20-39,40 mm, by the *female gender* between 8, 20 – 37, 30 mm, and by the *male gender* between 12,30- 39,40 mm.

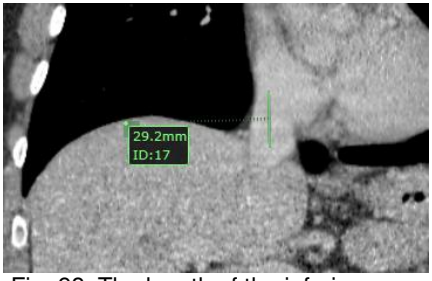


Fig. 98. The length of the inferior vena cava from the right hepatic vein to the end of the vena cava in the right atrium is of 29,2 mm (by the male gender).

Fig. 99. The diameter of the right renal vein is of 12,40 mm (by the female gender).

The diameter of the right renal vein has been found between 9,14 -15,90 mm, by the *female gender* between 9,14-13,64 mm, and by the *male gender* between 11,0-15,9 mm.

The diameter of the left renal vein has been found between 9,62-16,87 mm, by the *female gender* between 9,62-16,87 mm, and by the *male gender* between 10,1 -14,6 mm.

Fig. 101. The diameter of the left renal vein is of 14,38 mm (by the female gender).

Fig. 117. The diameter of the right hepatic vein (11,82 mm) is higher than the diameter of the middle hepatic vein (7,80 mm) with 3,98 mm, but shorter than the diameter of the left hepatic vein (12,34 mm) with 0,52 mm (by the female gender).

The diameter of the right hepatic vein has had a value between 6,03 -13,48 mm, by the *female gender* between 6,03-13,48 mm, and by the *male gender* between 7,7-11,10 mm.

The diameter of the middle hepatic vein has been found between 3,89-12,21 mm, by the *female gender*, it was between 3,89 -12,21 mm, and by the *male gender between* 6,03-12,0 mm.

The diameter of the left hepatic vein has been between 4,75 -13,36 mm, by the *female gender* between 5,41-13,36 mm, by the *male gender* between 4,75-1,60 mm.

DISCUSSIONS

TABLE 1. THE LEVEL OF FORMATION OF THE INFERIOR VENA CAVA IN RELATION TO THE SPINAL CORD.

AUTHOR	THE LEVEL OF FORMATION OF THE VCI
Testut	L4-L5 i.v. disc
Kamina	L5 sup
Gray	L5 ant.part
Gillot	L4-L5 i.v. disc.
Moore	L5 vrt.
Komreich	L3 sup. – S1 sup.
Schunke	L5 vert.
Piro	L4 vert.- S1 vert.
Ionescu	L4-L5 i.v. disc.- L5 ½ sup.
Burcut (2016)	L4 ½ sup.- L5 ½ inf.
Personal results	***L3-L4 i.v. disc.– L5 – S1 disc.***

TABLE 2. THE VALUE OF THE SUBCAV ANGLE.

AUTHOR	SUBCAV ANGLE
Testut	60-65º
Piro	69+/-21 (21-107º)
Shindo	75+/-21 (28-107º)
Capellades	73+/-17 (35-115º)
Ouimingo	72 (45-110º)
Ionescu	23,4-78,70º
Personal results	***51,0-74,70º***

TABLE 3. THE VALUES OF THE CAVOILIAC ANGLE RIGHT AND LEFT.

AUTHOR	RIGHT CAVOILIAC ANGLE	LEFT CAVOILIAC ANGLE
Shindo	127-175º	125-170º
Ionescu	155,40-179,0º	127,8-172,1º
Personal results	***137,70-169,0º***	***116,30-163,10º***

My results are lower than of [20] at the level of the minimum value of the right cavo iliac angle and at the both values of the limits of the left cavo iliac angle, but higher in respect to the maximal extreme value of the right cavo iliac angle with 4º. The results of [11] are higher with 10-17,5 ºin respect to the right cavo iliac angle and with 9,0 -11,50ºat the level of the left cavo iliac angle.

In respect to the ***caliber of the inferior vena cava***, from its formation to its end, this is very variable, being influenced by the end of its affluences, especially by the renal and hepatic veins. Thus, [1, 2] presents a diameter between 20- 32 mm, [4] presents a unequal caliber, at the end measuring 30 mm; [3] reports a diameter of 30 -40 mm, being between 17- 35 mm; [21] finds a medial diameter of 24, 26 mm, between 14 -33,3 mm; [22] reports a medial diameter of 24,26 mm, between 14-33,3 mm; [22] gives a medial diameter between 21+/-3,7 mm (real value); [23] finds a medial diameter of 20 mm, between 13-30 mm.

Most authors consider that the inferior vena cava presents two obvious dilatations, one at the level of the renal veins and the other one at the level of the hepatic veins. It has been concluded that the diameter of the inferior vena cava frequently lowers with 15-30 mm above its formation at approximatly 10-20 mm, so that before to the end of the renal veins to become bigger, this meaning that at the level of its formation the vena cava presents a first dilatation and that per total there would be three physiological dilatations, at the level of the renal and hepatic veins, being the second, furthermore the third cava dilatation.

TABLE 4. THE VALUE OF THE INFRARENAL CAV DIAMETER

AUTHOR	INFRARENAL CAV DIAMETER (MM)
Testut	24-26
Prigent	17
Brown	21+/-3,7
Bonnichon	21,3 (10-31)
Prince	20 (15-30)
Personal results	**Right infrarenal :17,6-28,70** **Left infrarenal: 18,54-30,67**

TABLE 5. THE VALUE OF THE EXTERNAL CAV DIAMETER AT SUPRAHEPATIC LEVEL.

AUTHOR	SUPRAHEP. VCI DIAMETER (mm)
Testut	**30-32**
Rouvière	**30**
Kamina	**30**
Joshi	15-30
Bonnichon	max. 33,3
Personal results	***infrahep. :18,80-33,40*** ***suprahep. :20,46-37,0***

TABLE 6. THE TOTAL LENGHT OF THE INFERIOR VENA CAVA.

AUTHOR	LENGHT(mm)
Testut	220-250
Rouvière	220
Kamina	200
Gillot	180-200
Personal results	***fem. gender: 187,10-262,20*** ***masc. gender :215,40-294,40***

TABLE 7. DOUBLE RENAL VEINS.

AUTHOR	NO. OF CASES	NO. OF DOUBLE VEINS	RIGHT	LEFT
Delmas	**20**	5	4	1
Iorga	**100**	14	2	12
Personal results	73	***9***	***7***	***2***

TABLE 8. MULTIPLE RIGHT HEPATIC VEINS

AUTHOR	METHOD	NO. OF CASES	VHDI	%
Couinaud (1958)	injection-corrosion	30	3	10
Masselot (1978)	injection-corrosion	80	10	12
Ton Than Tung (1979)	-	-	-	20
Nakamura (1981)	Necropsies	83	20	24
Gupta (1979,1981)	-	-	-	6
Makuuchi (1983)	Intraoperating Ultrasonography	269	18	7
Chevalier (1986)	Different	32	7	22
Champetier (1993)	injection-corrosion	125	-	9
Matusz (1998)	injection-corrosion	210	-	24
Dina (2012)	Different	192	23	8,85
Personal results	***Cavographies***	***48***	***8***	***11,67***

CONCLUSIONS

The inferior venous cav system represents the biggest venous collector of the human body, collecting the subdiaphragmatic venous blood which it flows into the right atrium; it drains 3/5 of the human body blood, it subjects it to a precise systematization, of embryological, anatomical and functional nature [Kamina]. To [Testus, Rouvière, Gillot] the inferior vena cava is the collector trunk of the blood from the whole subdiaphragmatic part of the body, carring to the heart the blood from the level of the digestive renal, genital system, as well as from the inferior members of the body. The anomalies and the variants of the inferior vena cava and its affluences, are often met, this being due to the complex embryological development of the IVC, each of its topographical segment having a characteristic development. All these, and especially the dilatation of the IVC, create problems to the surgeon in case he doesn't know about the anomaly, existing the risk of massive while operating hemorrhage. At the same time, the presence of such a anomaly contradicts the renal transplant and raises important problems in case of catheterization or in case of puncture of the femoral veins or the supra renal ones, it can be a suspect in the case of fibrinolysis in thrombosis, especially at the level of the left inferior member [Peltier]. To [Kleeman] the laparoscopic approach at the level of L4- l5 is complicated by the variability of the vascular anatomy dealt with at this level; the usual magnetic resonance imaging or computerized tomography can be used in order to classify the vascular anatomy and plan a optimal approach; the avoidance of the left part of the IVC or of the left common iliac vein can lower the risk of ejaculation disfunction".

The morphometry of the IVC, especially its diameter at different levels, in relation to the end of its bigger affluences is of great importance in executing the grafts or in the implantation of the anti- thrombosis devices, which according to [Prigent, Price] a selective place is represented by the infra renal segment of this.

To [Ferraz] "the endovascular holes of the IVC have a elliptical contour on a transversal section, which would result because of a thickening of the longitudinal muscular layer. A great

number of groups are in a continuity with the muscular fibers of the transversal muscular layer. Elastic fibers at the end have been rarely observed in relation to the muscular fibers of the vena cava, these being absent in the hepatic veins".

The horizontal endocav diameters have been found longer than the vertical ones, the cava ostium having a oval form, with the big ax transversal, oblique supero lateral or infero lateral. The endocava diameters of the IVC have shown a caudo cranial growth, according to the end of its voluminous affluence, in most of the cases the biggest growths being observed above the end of the hepatic veins and not above the renal veins, as [Testut, Rouviere] has affirmed, these saying that this growth in caliber is more obvious at this level than at the level of the hepatic veins. An exception from our supposition is made by the vertical diameter by the male gender, which has shown a bigger growth at the supra renal level, with 3, 66 mm more than by the suprahepatic level.

The IVC's morphometry is of a great importance in surgery, in positioning the graft of the IVC, recent studies showing that approximately 7-10% of the pacients who have gone through chimiotherapy after the desection of the retro peritoneal lymphatic lumbs have needed the resection of the IVC [Albers, Winter].

There are very rarely met the studies which approach the morphology of the IVC according to gender.

Between my results and the ones in the consulted literature, there can be seen some significant differences, these being due especially to the number of cases on which the study has been conducted [for example, Ionescu has worked on only 18 cases]. A lot of authors consider the existence of the morphological differences according to the rase and even ethny, but the variants are also dependent on gender, age, but especially on the working methods, other results being obtained when the morphometry is done on formolised bodies, fresh bodies, or with the help of injection of plastic substances, the measurements done by an ecograph or computer tomograph being more precise, but even here differences according to the incidence under which the studies have been done can exist, they can depend as well on the experience of the person who does the research.

This demonstrates the importance of pre implentary cavography in order to find out the real value of the diameter of the IVC before the positioning of the filter, so that the migration of the already implanted filters can be hindered [Brown]. The importance of

the methods of the measuring of the veinal diameters results therefore, [acc. to Bonnichon] there are today six methods of determining the diameter of the IVC: anatomically, sonographically, radiologically (after the positioning of the filter), cavography, computer tomography (CT) and magnetic nuclear resonance. It is considered that the anatomically, radiologically and sonographically methods are a matter of contradictions, fact which places the results under the question and according to him the CT examination seems to be a better way to calculate the different diameters of the IVC.

According to [Brown], the using of a calibered intravascular catheter gives the most precise modality of measuring the diameter of the IVC.

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