Surg Radiol Anat (2010) 32:17–24
DOI 10.1007/s00276-009-0534-7

ORIGINAL ARTICLE

Anatomical considerations on the corona mortis

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Received: 12 April 2009 / Accepted: 9 July 2009 / Published online: 28 July 2009

Abstract The *corona mortis* (CMOR) represents the vascular connection of the obturator and external iliac systems. We aimed to evaluate by dissections the morphological possibilities of the CMOR and their individual combinations. For the study we used 20 human adult cadavers that were bilaterally dissected (40 hemipelvises), with evidences of the vascular elements at the level of the superior pubic branch in 32 (80%) of hemipelvises. The morphological patterns we identified were classified in three types (I–III): I. arterial CMOR (10 hemipelvises): I.1. obturator artery (OA) from the external iliac artery (EIA); I.2. OA from the inferior epigastric artery (IEA); I.3. anastomosis of the OA and IEA; I.4. pubic branches of the OA, in the absence of any anastomosis with the EIA system; II. venous CMOR (6 hemipelvises): II.1. obturator vein (OV) draining into the external iliac vein (EIV); II.2. OV draining into the inferior epigastric vein (IEV); II.3. venous anastomosis of the OV and IEV and III combined, arterial and venous CMOR (16 hemipelvises). We classified the combined *coronae mortis* in nine different subtypes that mainly (but not exclusively) correspond to various combinations of types I and II. The surgical relevance of the vascular relations of the superior branch of pubis (in trauma, orthopedic approaches, hernia repair, embolizations and intra-arterial infusions) recommends a detailed knowledge of the morphological and topographical possibilities of the *crown of death* and the individual evaluation of this risky anatomical structure.

Keywords Pelvis · Pubis · Iliac vessels · Obturator vessels

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Introduction

The *corona mortis* is defined as the vascular connections between the obturator and external iliac systems [1, 5, 18].

The name "*corona mortis*" or crown of death testifies to the importance of this feature, as significant hemorrhage may occur if accidentally cut and it is difficult to achieve subsequent hemostasis [5].

Darmanis et al. (2007) [5] brought arguments to sustain a paradox: in anatomical dissections a large vessel was identified behind the superior pubic ramus, whereas in clinical practice this vessel does not seem to be as great a threat as initially perceived.

Although the *corona mortis* is usually regarded as arterial, it may be arterial or venous or both [18]; the diameter of the connecting vessel ranges from 2.0 to 4.2 mm [10]. It seems that there are no significant differences between genders in the incidence of *corona mortis* and the distance between communicating vessels and the symphysis pubis [18].

The knowledge of accurate anatomy of *corona mortis* provides the great advantage in decreasing the incidence of surgical complications and improve the result of operations [19].

We aimed to study by detailed anatomical dissections and systematize the morphological possibilities of the vascular connections that are generally termed *corona* mortis (CMOR).

Materials and methods

We performed the present anatomical study by anatomical dissections in 20 human adult cadavers (12 males, 8 females); bilateral dissections of the 40 hemipelvises (termed here specimens) were performed using the anterior–superior approach. The external iliac vessels, psoas major muscle, lateral pelvic wall, obturator vessels and nerve were carefully dissected and the vascular elements on the superior branch of the pubic bone were evidenced.

We only identified the vessels as "*large*" and "*thin*", taking into account the fact that a practitioner will not identify these vessels based upon their exact caliber but he will evaluate them based upon their appearance, topography and connections.

The results were documented using digital photography.

Terminology

We termed *corona mortis* as any vessel coursing over the superior pubic branch, no matter whether it was a vascular anastomosis, an obturator vessel related to the external iliac system or a terminal small vessel.

We evaluated as obturator artery any single artery coursing towards the upper border of the obturator foramen, regardless of its origin. If different arteries were reaching that border of the obturator foramen, we evaluated the largest one as obturator artery and the others as accessory obturator arteries. If we encountered more accessory obturator arteries, we evaluated as aberrant accessory any artery that was entering the obturator foramen but not at its upper border. We used a similar terminology for veins.

IIA	internal iliac artery
EIA	external iliac artery
IEA	inferior epigastric artery
OA	obturator artery
AOA	accessory obturator artery
AAOA	aberrant accessory obturator artery
CMOR	*corona mortis*
OV	obturator vein
EIV	external iliac vein
IEV	inferior epigastric vein.

Results

The *corona mortis* (CMOR) was identified on the superior pubic branch in 32 (*n*) of the 40 (n) hemipelvises we dissected (80%). In what concerns the vascular composition of CMOR, our results mainly suggest there is a wide variability of it.

We identified 26 hemipelvises (65% of 40 pelvic halves, 81.25% of the 32 specimens positive for the presence of the *corona mortis*) with arterial elements crossing over the superior pubic branch and 22 hemipelvises (55% of 40 pelvic halves, 68.75% of the 32 specimens positive for the presence of the *corona mortis*) with venous elements at that level.

Regarding the vascular composition of the CMOR, we identified in our specimens three types: type I, corresponding to a pure arterial CMOR (10 hemipelvises); type II, of a pure venous CMOR (6 hemipelvises) and; the most frequent, type III, consisting of both arterial and venous connections located on the superior branch of pubis (16 hemipelvises).

We classified the arterial anastomoses (type I of CMOR) we found into four subtypes (Fig. 1):

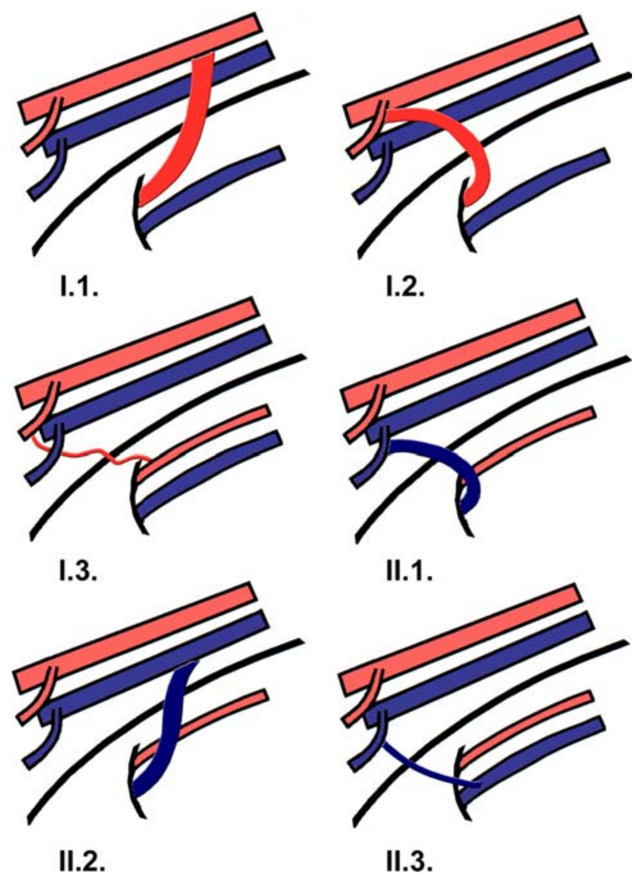

Fig. 1 Diagrams of the main pure arterial and venous CMOR types and subtypes. These will variably associate to form combined CMOR

I.1.Obturator artery (OA) emerged from the external iliac artery (EIA), 1 hemipelvis;
I.2.OA leaving the inferior epigastric artery (IEA) (Fig. 2), 3 hemipelvises;
I.3.anastomosis of the OA and IEA (Fig. 3), 5 hemipelvises;
I.4.pubic branch(es) from the OA, unanastomosed to the external iliac system but crossing over the superior pubic branch, 1 hemipelvis

As for the second type of CMOR, the pure venous one, we identified three subtypes (Fig. 1):

- II.1. obturator vein (OV) draining into the external iliac vein (EIV), 1 hemipelvis;
- II.2. OV draining into the inferior epigastric vein (IEV), 2 hemipelvises;
- II.3. venous anastomosis of the OV and IEV (Fig. 4), 3 hemipelvises.

Most of our specimens presented various combinations of arterial and venous *coronae mortis* (Figs. 5, 6, 7, 8; Table 1); it can be observed that most of the arterial and venous anastomoses that came into combinations were already identified as subtypes of the pure vascular *coronae mortis*, arterial or venous [except a specimen where the venous component of CMOR was a large anastomosis of the external iliac and obturator veins (Fig. 6)].

We found that the position of the veins in relation to the arteries that may cross the superior pubic branch is variable: the vein may be either distal (Fig. 6) or proximal (Fig. 7) to the artery if we refer to the obturatory vessels, while the arterial/venous anastomoses intermingle with the large vessels. Anyway, the relative position of the arterial and venous *coronae mortis* seemed related to the vessel these were linked to. The link of the CMOR to the inferior epigastric vessels brought it closer to the femoral ring and inguinal and lacunar ligaments while its link to the external iliac vessels distanced it to the femoral ring, but this may not be a strict rule.

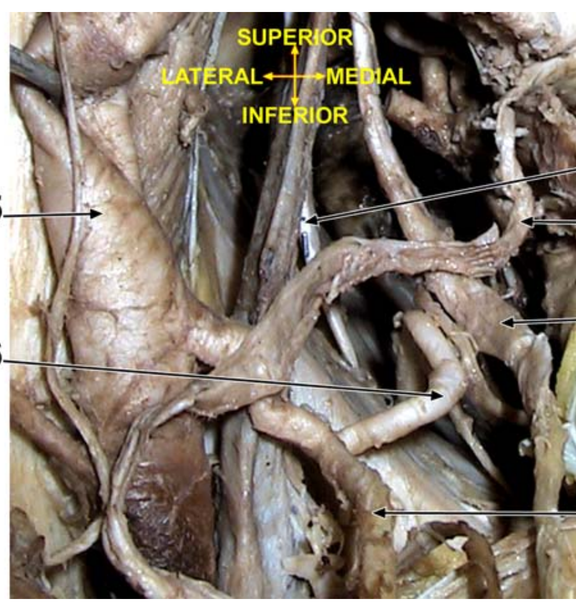

Fig. 2 The right side, arterial CMOR (type I.2., obturator artery leaving the inferior epigastric artery), female cadaver. *1* obturator nerve, *2* round ligament of uterus, *3* cord of the umbilical artery, *4* inferior epigastric artery, *5* external iliac artery, *6* obturator artery

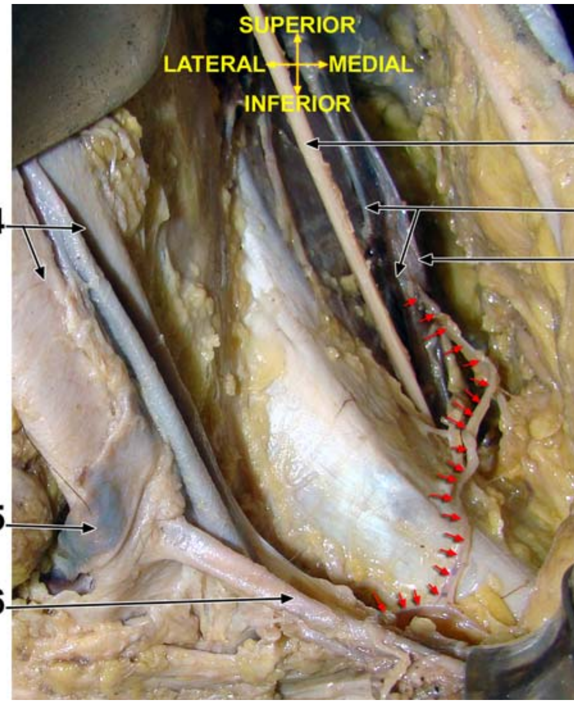

Fig. 3 The right side, arterial CMOR (type I.3, *arrows* the anastomosis of the obturator and inferior epigastric arteries), male cadaver. *1* obturator nerve, *2* obturator artery, *3* obturator vein, *4* external iliac vessels, *5* deep iliac circumflex vein, *6* inferior epigastric artery

Discussion

Vascular variations have always been a subject of controversy, as well as curiosity, because of their clinical significance. There is no artery of proportionate size having as variable an origin as that of the obturator artery [14]. The variant obturator arteries crossing the superior pubic branch are those leaving either the external iliac artery, or the inferior epigastric artery that we found, in 12.5 and 15.62%, respectively. In the literature their incidence is highly variable: the origin of the OA from the EIA is reported in 0–25% of cases, while the origin of the OA from the IEA ranges from 6.6 to 44% (Table 2).

There is an important variation of the reported incidences of the *corona mortis* (Table 3); we agree with Okcu et al. (2004) [18] who considered that this variation may be

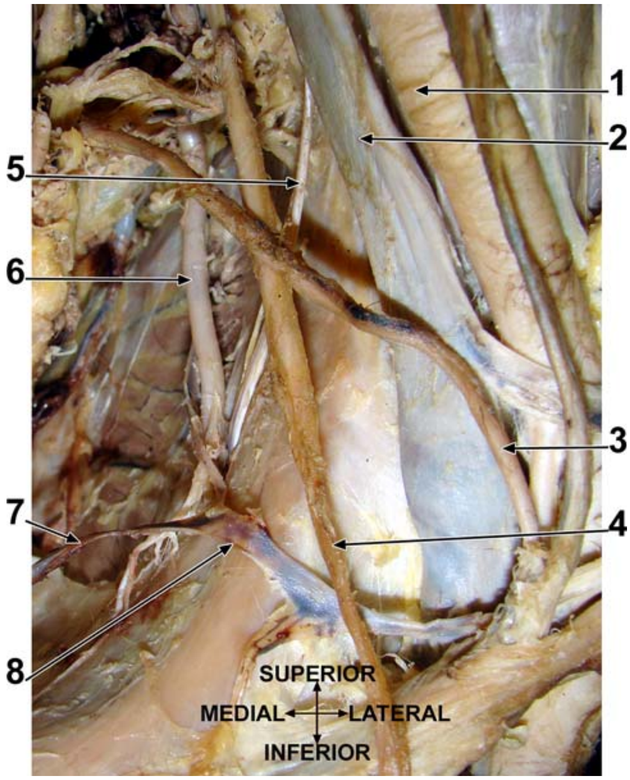

Fig. 4 The left side, venous CMOR (type II.3., venous anastomosis of the obturator and inferior epigastric veins), male cadaver. *1* external iliac artery, *2* external iliac vein, *3* deferent duct, *4* cord of the umbilical artery, *5* obturator nerve, *6* obturator artery, *7* retropubic vein, *8* venous CMOR connecting the obturator and inferior epigastric veins

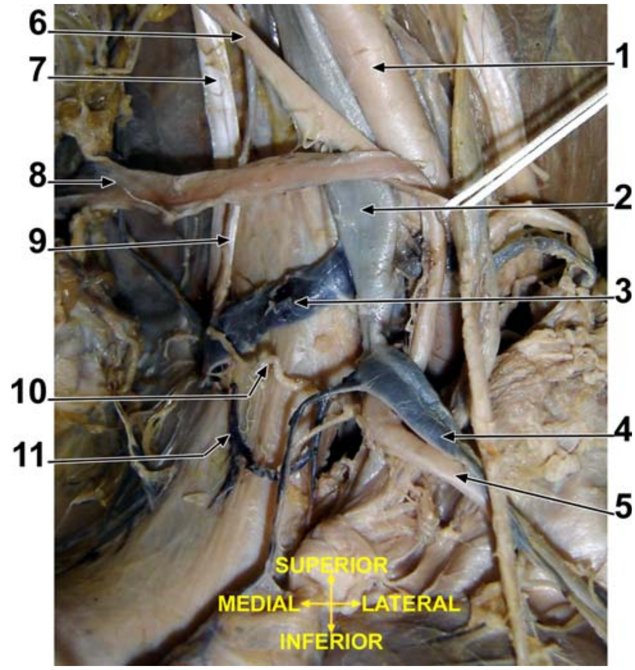

Fig. 5 The left side, combined, arterial and venous CMOR, male cadaver. *1* external iliac artery, *2* external iliac vein, *3* obturator vein draining into the external iliac vein, *4* inferior epigastric vein, *5* inferior epigastric artery, *6* cord of the umbilical artery, *7* obturator nerve, *8* deferent duct, *9* obturator artery, *10* arterial anastomosis of the obturator and inferior epigastric arteries, *11* venous anastomosis of the obturator and inferior epigastric veins

due to: (1) regional differences in the development of the vascular system and (2) difficulties in dissecting the collapsed vessels in cadavers and the limitations caused by the size of the vessels. Moreover, the hazard of specimens must be taken into account.

There is a lack of consensus in what regards the terminology: there are authors considering as accessory OA [1] or aberrant OA [4, 15, 19] those anatomic variants with OA emerging from the external iliac system and there are authors, like us, considering as OA any major vessel, no matter its variant of origin, that enters the obturator canal as a significant supplier [17, 20, 22].

Our proposed terminology seems more logical: a normal OA may present with a variable origin while an accessory artery must be accessory to a different one and not by itself; in the absence of any other obturator arteries, the only existing one must be considered OA. An aberrant artery refers to a vessel with an aberrant course and so, aberrant OA may be termed an OA emerging from the external iliac system or an OA aberrantly coursing through the obturator foramen; at times as we consider the OA emerging from the external iliac system as an usual variant, the term aberrant will only apply to the aberrant passage through the obturator foramen. These observations leaded us to the following definitions:

Normal OA an OA leaving the iliac arterial systems and coursing through the obturator canal;

Accessory OA a supplemental artery found in the presence of a normal OA, also coursing through the obturator canal;

Aberrant OA supplemental artery, with OA present, but with an aberrant course through the obturator foramen.

It is highly recommended to follow the last revision of the Latin anatomical terminology (TA) in any educational, scientific, translating, editing, revising and publishing activities [12].

Based on Senior's embryological description (1919, 1925), Sañudo et al. advanced in 1993 an ontogenetic theory involving individual variations of differentiation of vessels from the *rete femorale* and *rete pelvicum*. The arterial pattern is established after the individual selection of the channels comprising these primitive networks [20]. There are channels that enlarge whilst others retract and disappear. Based upon the ontogenetic theory of Sañudo we present here (Fig. 9) the diagrams that correspond to the arterial variants CMOR-related ontogenesis and also to the concomitant presence of the accessory and accessory aberrant

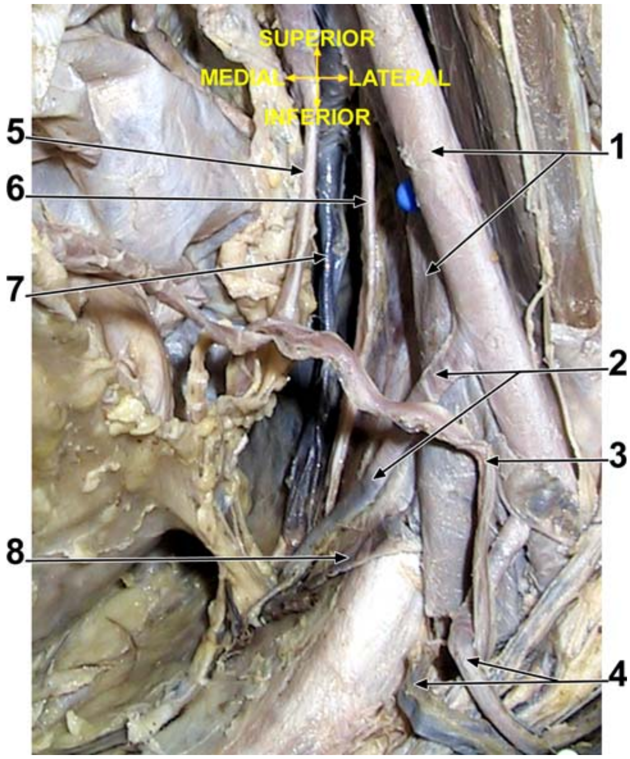

Fig. 6 The left side, combined, arterial and venous CMOR, male cadaver. *1* external iliac vessels, *2* obturator artery leaving the external iliac artery, *3* deferent duct, *4* inferior epigastric vessels, *5* cord of the umbilical artery, *6* obturator nerve, *7* obturator vein, *8* large venous anastomosis of the obturator and external iliac veins

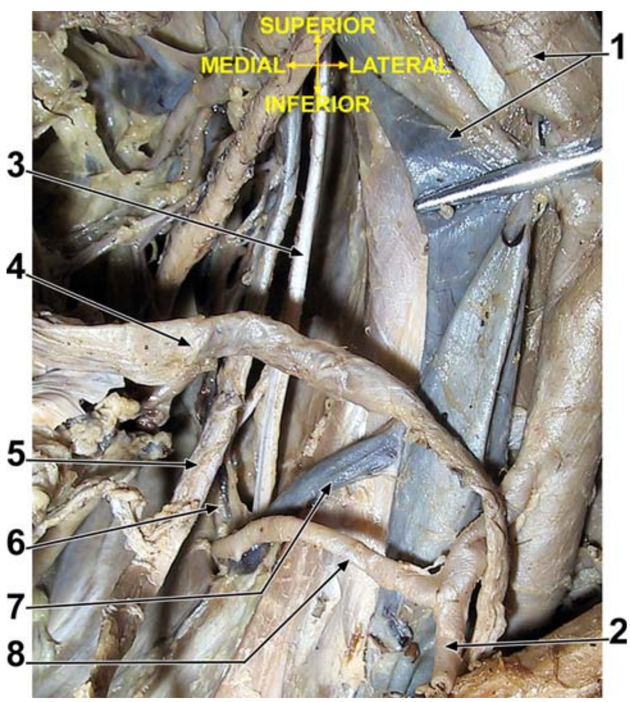

Fig. 7 The left side, combined, arterial and venous CMOR, male cadaver. *1* external iliac vessels, *2* inferior epigastric artery, *3* obturator nerve, *4* deferent duct, *5* cord of the umbilical artery, *6* obturator vein, *7* venous anastomosis of the external iliac and obturator veins, *8* obturator artery

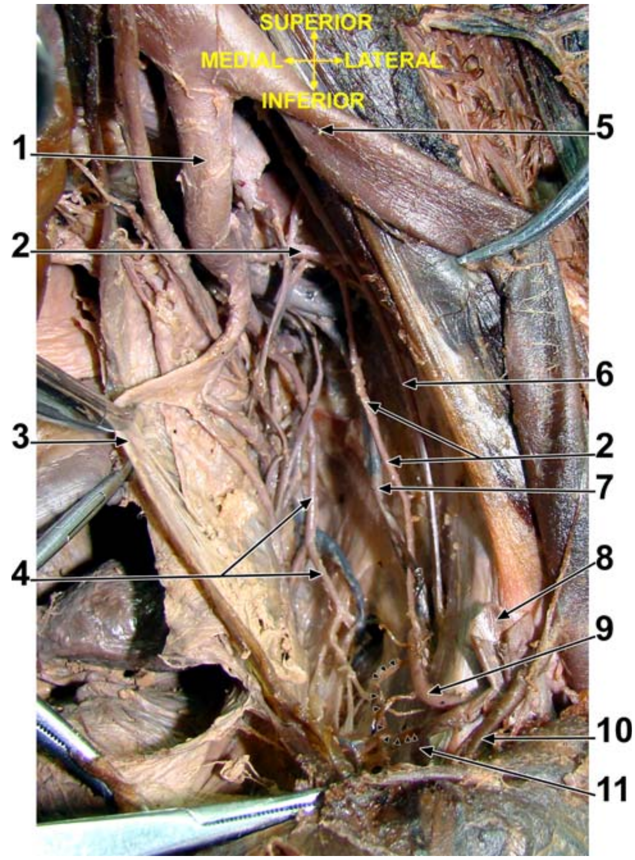

Fig. 8 The left side, combined, arterial and venous CMOR, male cadaver. *1* internal iliac artery, *2* accessory obturator artery, from the posterior division of the internal iliac artery, *3* cord of the umbilical artery, *4* aberrant accessory obturator artery, from the superior gluteal artery, *5* external iliac artery, *6* obturator nerve, *7* obturator vein, *8* external iliac vein, divided; *9* obturator artery, *10* inferior epigastric artery, *11* inferior epigastric vein. *Arrowheads* the venous anastomosis of the obturator and inferior epigastric veins

Table 1 Combined, arterial and venous, *coronae mortis* (type III)

Arterial component(s)	Venous component(s)	Number of hemipelvises
Anastomosis OA-to-IEA	OV draining into IEV Anastomosis OV-to-IEV	1
OA from EIA Anastomosis OA-to-IEA	Anastomosis OV-to-IEV	2
OA from IEA	OV draining into IEV	1
Anastomosis OA-to-IEA	Anastomosis OV-to-IEV	5
Pubic branches of OA	Anastomosis OV-to-IEV	2
Anastomosis OA-to-IEA	OV draining into EIV Anastomosis OV-to-IEV	2 (Fig. 5)
OA from EIA	Anastomosis of the OV and EIV	1 (Fig. 6)
OA from IEA	OV draining into EIV	1 (Fig. 7)
OA from IEA[a]	Anastomosis OV-to-IEV	1 (Fig. 8)

[a] The cadaver also presented on that side an accessory and an aberrant accessory obturator arteries

Table 2 Incidences of the obturator artery origins from the external iliac system

Authors	OA from the EIA (type I.1.) (%)	OA from the IEA (type I.2.) (%)	Number of specimens
Bergman et al. (1988) [2]	1.1	25	–
Jakubowicz and Czarniawska-Grzesińska (1996) [11]	1.3	6.6	75 specimens (lower limbs)
Missankov et al. (1996) [16]	25	44	49 pelvic halves
Berberoğlu et al. (2001) [1]	7.14	7.14	14 cadaver halves
Sarikcioglu et al. (2003) [22]	0	14.81	54 cadaver halves
Current study	12.5	15.62	32 hemipelvises

Table 3 Incidence of various connections (vascular, arterial and venous) that cross the superior pubic branch, as resulted from the references and the present study

Reference	Vascular connections crossing the superior pubic branch (%)	Arterial connections crossing the superior pubic branch (%)	Venous connections crossing the superior pubic branch (%)	Specimens
Missankov et al. (1996) [16]	–	–	46	49 cadaver halves
Tornetta et al. (1996) [24]	84	34	70	50 cadaver halves
de Kleuver et al. (1998) [6]	25	–	–	24 hemipelvises
Berberoğlu et al. (2001) [1]	–	–	100	14 cadaver halves
Karakurt et al. (2002) [13]	–	28.5	–	98 patients, angiography
Sarikcioglu et al. (2003) [22]	–	0	20.37	54 cadaver halves
Hong et al. (2004) [10]	72	–	–	50 hemipelvises
Okcu et al. (2004) [18]	61	19	52	150 cadaver halves
Pungpapong and Thum-umnauysuk (2005) [19]	77.27	–	–	66 pelvic halves
Darmanis et al. (2007) [5]	83	–	–	80 hemipelvises
Current study	80	65	55	40 hemipelvises

obturator arteries we evidenced in type III.9 of CMOR; the AOA we evidenced in that case left the posterior trunk of the IIA and thus it corresponds to the variant OA reported by Kumar and Rath in 2007 [14] with a similar origin but in a single, CMOR-negative, hemipelvis from 316 dissected pelvises (0.15%). As for the AAOA, we did not find any reported comparable variant.

The large spectrum of combined CMOR we evidenced appeared to us to be highly relevant to the surgical practice. This fact imposes that surgeon, when operating at the superior pubic branch, must evaluate free of any prejudgement the presence and the vascular pattern of CMOR. The angiography can only evaluate the arterial CMOR's, without orienting the surgeon on the venous anatomy of the superior pubic branch.

Secin et al. (2007) [23] stated that on the superior pubic branch the obturatory vein is always distal to the artery. We present here evidences for the variable intrinsic relation of these two vessels: the vein is variably located, either proximal or distal to the artery.

Berberoğlu [1] observed that the venous arch over the superior pubic branch was in close relation with the femoral ring and lacunar ligament; our results indicate that in fact this is true only if that venous arch is linked to the inferior epigastric vein or to the distal end of the external iliac vein but it seems false when that arch links to the external iliac vein at distance from the femoral ring.

Sarikcioglu and Sindel (2002) [21] reported a combined CMOR formed by an obturator artery leaving the external iliac artery and an anastomosis of the obturator and inferior epigastric artery; correlating with our classification, it is the combination I.1. + II.3. and thus it strongly resembles but not identical with our type III.2.

It was also reported as rare (1%) a common trunk leaving the external iliac artery and sending off the obturator, inferior epigastric and profunda femoris arteries [3]. Also two cases were reported in which the obturator, inferior epigastric and medial circumflex femoral arteries arose from a common trunk from the external iliac artery [20]. In our specimens we did not identify comparable morphological patterns.

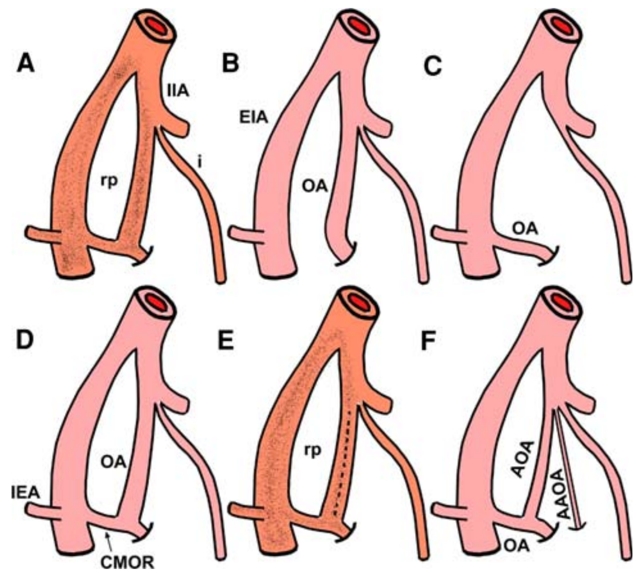

Fig. 9 Diagrams based on the ontogenetic theory of Sañudo on the individually variable vascular modeling of the vascular channels that compose the *rete pelvicum* (rp/*dotted areas* in **a**, **e**). **b** OA from the IIA, lack of an arterial CMOR; **c** OA from the external iliac system (EIA or IEA); **d** OA from the IIA and arterial CMOR present; **e** from *rete pelvicum* a primitive OA develops and may split; **f** splitting the primitive OA can lead to distinctive AOA and AAOA

Table 4 As resulted from different studies, the distance between the *corona mortis* and the symphysis pubis is variable

Reference	Range distance from the CMOR to the symphysis pubis (mm)	Number of specimens
Tornetta et al. (1996) [24]	30–90	50 cadaver halves
Karakurt et al. (2002) [13]	21.4–41	98 patients, angiography
Hong et al. (2004) [10]	38–68	50 hemipelvises
Darmanis et al. (2007) [5]	40–96	80 hemipelvises

The distance between the CMOR and the pubic symphysis was considered relevant for surgeons and it was evaluated in various studies ranging from 21.4 to 96 mm. (Table 4). We consider that at times the possibility for a combined CMOR to occur exists, the surgeons must evaluate directly, with caution, the location and intrinsic relations of the vessel(s) over the superior pubic branch. Distances from these vessels to bony landmarks are individually variable, gender-related and anthropological types-related, and so, their knowledge appears to us of reduced utility and reliability.

Being closely related to the superior pubic branch, the acetabulum and the femoral ring (and, eventually, a femoral hernial sac) [1], the CMOR is at risk in groin or pelvic surgeries. Failure to ligate these vessels will be followed by their retraction in the obturator canal after being injured [7].

CMOR is prone to damage: (a) after benign pubic branch fractures that can lead to significant hemorrhage due to avulsions of CMOR [9]; fracture lines involving the superior part of the obturator foramen, the superior pubic ramus, or the pubic acetabulum that are prone to cause injury to the obturator artery [25]; (b) during the ilioinguinal or the intrapelvic approaches to the acetabulum and pelvis [5, 10, 22]; (c) after coil embolization of the IIA branches for managing hemorrhage due to pelvic fractures, the variations in origin of the OA may be additional sources of bleeding [4]; (d) in pelvic osteotomies for acetabular dysplasia that use the medial approach and so interfere with the CMOR [6]; (e) in laparoscopic hernia repair the injury to CMOR could happen during dissection of the preperitoneal space and hernia sac; the vessels can also be injured from tacker used for fixing the mesh to abdominal wall; an injury of CMOR may need conversion from laparoscopic hernia repair to open surgery to stop the bleeding [19]; (f) also, a case was reported of a patient who developed, due to the existence of an arterial *corona mortis*, a skin rash in his right lower abdominal wall after an intra-arterial infusion chemotherapy for carcinoma of the bladder [8].

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