Hernia (2016) 20:659–665
DOI 10.1007/s10029-015-1444-8

ORIGINAL ARTICLE

Corona mortis: in vivo anatomical knowledge and the risk of injury in totally extraperitoneal inguinal hernia repair

M. Ates[1,2] · E. Kinaci[3,4] · E. Kose[2] · V. Soyer[1] · B. Sarici[1] · S. Cuglan[2] · F. Korkmaz[2] · A. Dirican[1]

Received: 27 June 2015 / Accepted: 6 November 2015 / Published online: 30 November 2015

Abstract
Purpose Corona mortis (CMOR) is the arterial and/or venous vascular communication(s) between the obturator and external iliac vessels. Totally extraperitoneal (TEP) inguinal hernioplasty can be associated with vascular complications especially during the fixation of the mesh. Theoretically, CMOR is an important nominee. But, the data in literature are insufficient about CMOR injury. Additionally, most of the studies about CMOR have been usually performed on cadavers. We aimed to reveal the preperitoneal vascular anatomy of inguinal area and provide in vivo knowledge about CMOR. The risk of arterial injury was also evaluated.
Materials The data of preperitoneal vascular anatomy of 321 patients who underwent TEP procedure between January 2005 and July 2014 were retrospectively evaluated.
Results Mean age was 46 ± 8.9 years, 53 females vs 268 males. 391 hemipelvises were evaluated. Two types of arterial structure were identified; (1) an aberrant obturator artery forming an anastomosis with branches of ordinary obturator artery; (2) a pubic branch of inferior epigastric artery. The incidence of arterial CMOR was 28.4 % and of any arterial structure was 45.0 %. An arterial CMOR was considered as thick (≥2 mm) or thin (<2 mm). Injury of arterial CMOR during tack stapling on Cooper's ligament was seen in six cases (1.5 %). All of them were thin (<2 mm) in structure. Venous CMOR was visible only under low pressure in work space.
Conclusion During TEP hernia repair, CMOR and/or pubic branch of inferior epigastric artery can be damaged. To prevent this complication, tacks should be stapled to Cooper's ligament close to symphysis pubis and dissection should be careful on the posterior surface of superior pubic ramus. Small caliber (<2 mm) arterial CMOR is more prone to be injured during TEP procedure. To explore venous structures properly, pressure in workspace should be kept as low as possible.

Keywords Anastomosis · Bleeding complications · Corona mortis · Groin · Inferior epigastric artery · Inguinal · Laparoscopic · Obturator artery · Retropubic · TEP

Introduction

Although corona mortis (CMOR) (also called Crown of Death) has been defined classically as an arterial anastomosis between obturator artery and external iliac artery in Anatomy Textbooks, currently in literature the widely accepted definition includes the arterial and/or venous vascular communication(s) between the obturator and external iliac vessels (Fig. 1) [1–7]. CMOR is clinically important due to the potential risk of bleeding in pelvic fractures [8, 9], pelvic and acetabular operations [10],

E. Kinaci works in fellowship program.

✉ E. Kinaci
erdemkinaci@gmail.com

1 Department of General Surgery, Faculty of Medicine, Inonu University, Malatya, Turkey

2 Department of Anatomy, Faculty of Medicine, Inonu University, Malatya, Turkey

3 Department of General Surgery, Faculty of Medicine, Inonu University (Works in fellowship program), Malatya, Turkey

4 Department of General Surgery, Istanbul Training and Research Hospital, Istanbul, Turkey

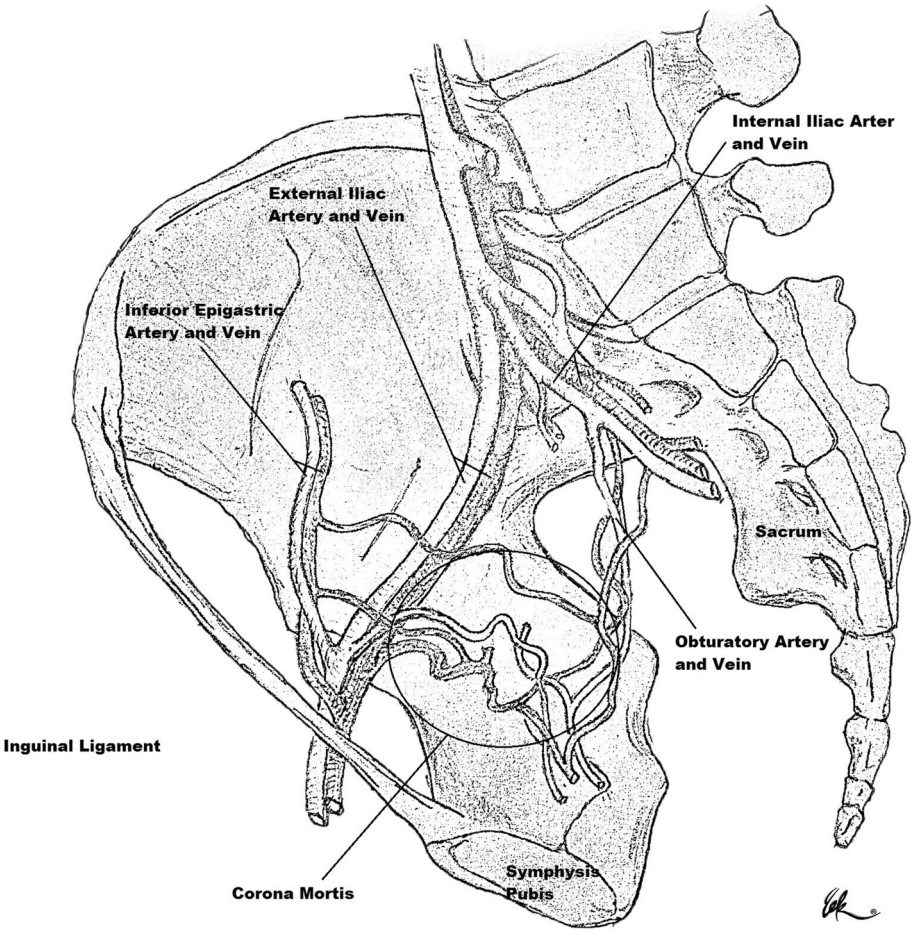

Fig. 1 General view of corona mortis

surgery for urinary incontinence [11], oncological pelvic dissections [6] and laparoscopic hernia repair [12, 13]. Therefore, it requires special interests from different surgical branches, such as orthopedics, oncologic surgery, urogynecology and general surgery.

Currently, there is a great consensus on laparoscopic approaches for inguinal hernia repair, transabdominal preperitoneal repair (TAPP) or totally preperitoneal repair (TEP). They can be performed for all groin hernias, inguinal or femoral, unilateral or bilateral, primary or recurrent [14]. Although it is rare, CMOR can be damaged during fixation of the mesh on Cooper's ligament in laparoscopic hernioraphy that can cause uncontrollable bleeding, retroperitoneal hematoma, conversion to open surgery and reoperation [12, 13, 15]. Therefore, vascular anatomy of retropubic area, especially CMOR, should be kept in mind by surgeons performing laparoscopic surgery for hernia repair. In literature, the anatomical data have usually been come from studies performed on cadavers. The aim of this study was to provide in vivo knowledge about CMOR in patients who underwent TEP repair. Additionally the risk of vascular injury was also evaluated.

Materials and methods

Three-hundred and seventeen patients underwent TEP hernia repair from January 2005 to July 2014 in Malatya State Hospital Department of General Surgery and Inonu University Faculty of Medicine, were evaluated. Data were collected prospectively and the study was prepared retrospectively. Permission was obtained from Inonu University Ethic Committee, and a written consent for surgical intervention was taken from each patient.

The operations were carried out in the standard fashion by the same operation team. In each operation, three trocars were placed in the midline inferior to umbilicus. Preperitoneal space was filled with CO_2 at the level of 14 mmHg to provide a workspace. The entire inguinal anatomy and the anatomical landmarks were recognized. At this stage of the operations, retropubic area was inspected and all vascular structures were noted at the end of operation by the surgeon. After reduction of the hernia, a polypropylene mesh was used to overlap the defect widely and fixed with endo-staples. One or two staples were placed onto the Cooper's ligament as closed as possible to symphysis

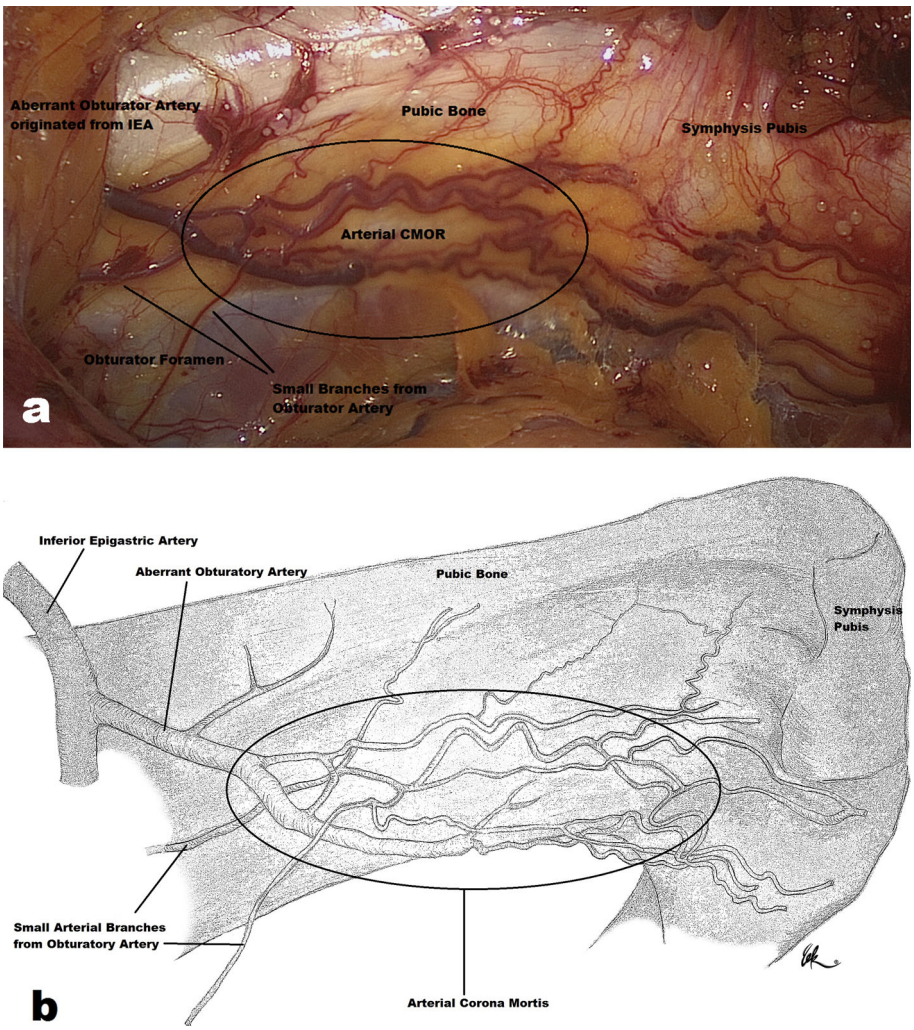

Fig. 2 **a**. Posterior view of left inguinal area under the pressure of 14 mmHg. Small arterial branches originating from inferior epigastric artery (IEA) and obturator artery combine to form arterial corona mortis (CMOR) just on superior ramus of pubic bone. **b**. Illustration of the **a**

pubis. Once correct positioning of the prosthesis and hemostasis had been checked. After exsufflation, the sac collapsed over the mesh. The trocars were removed under direct vision.

In this study, arterial and/or venous vascular communication(s) between the obturator and external iliac vessels and additionally nonanastomosing aberrant obturator artery running just superior to inguinal ligament were defined as CMOR.

Demography of the patients was enrolled. Vascular structures were identified according to its origin, thickness and presence of pulsation. Thickness of anastomosing artery was estimated by comparing with the tip of endodissector which is 2 mm in diameter. According to this cut-off value, the cases were considered as thick ($\geq$2 mm) or thin (<2 mm). Traces of vasculature and presence or absence of the visible anastomosis were noted. Non-anastomosing aberrant obturator artery was evaluated separately. Vascular injuries were also noted.

Although CMOR can be present bilaterally, symmetry is very rare [4]. Therefore, almost all reported series about CMOR has designed on "hemipelvis". Likewise, presence and nature of CMOR were also noted as "hemipelvis" in this study.

Results

Mean age was 46 $\pm$ 8.9 years, 53 cases were female and 268 cases were male. 244 cases were unilateral, 77 cases were bilateral. 398 hemipelvises were evaluated. In this paper, all of the determined structures were arterial. Although thin venous structures were seen in some cases, venous CMOR was not properly identified in great majority of the cases.

We determined two types of arterial structure: First; Aberrant obturator artery originated from inferior epigastric artery than crossing the superior pubic ramus and moving towards the obturator foramen, here, forming an anastomosis with branches of ordinary obturator artery (Fig. 2). Second; An arterial branch originated from inferior epigastric artery (IEA) (Pubic branch of IEA) than running parallel to superior border of pubic ramus towards symphysis pubis and separated to its terminal branches

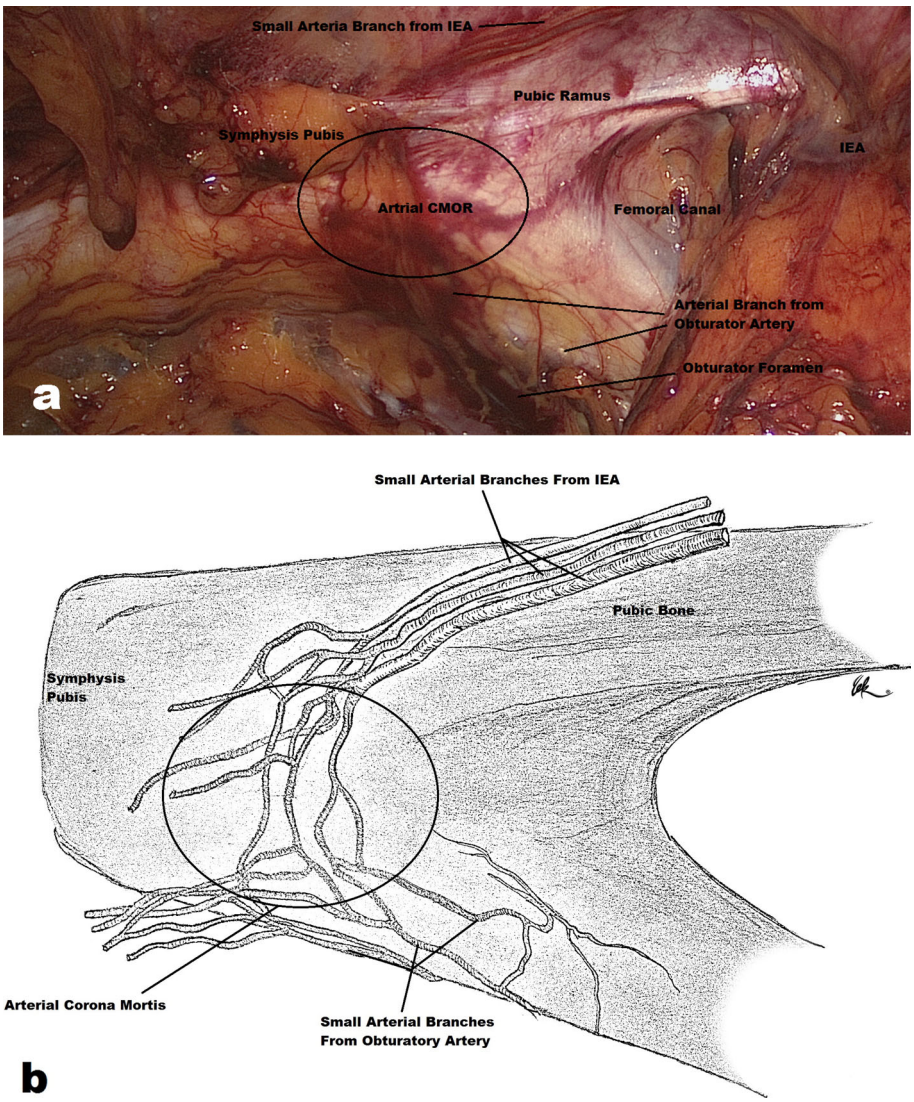

Fig. 3 **a**. Posterior view of right inguinal area under the pressure of 14 mmHg. An arterial branch of inferior epigastric artery (IEA) runs parallel to the superior pubic ramus towards the symphysis pubis, then gives small branches to form arterial corona mortis (CMOR). **b**. Illustration of the **a**

(Fig. 3). In the last few cases of this case series, we realized that the venous structures were visible, if the pressure was decreased to 10 mmHg (Fig. 4).

Overall results were detailed in Table 1. The incidence of the presence of an arterial structure in a retropubic area was 45.0 %. A polypropylene mesh was implemented in each of 398 hemipelvises by stapling on Cooper's ligament as close as possible to symphysis pubis. Injury of arterial CMOR during stapling of tacks was seen in six hemipelvises of six patients. All of the injured arteries were smaller than 2 mm in diameter. Therefore, we were obliged to convert to open surgery for hemostasis. There was no injury of venous structures.

Discussion

The term "Corona Mortis" is consisted of two Latin words; "corona" used in anatomical nomenclature to designate a crown-like eminence or encircling structure, and "mortis" comes from the term "mort" which means "death". Definition of CMOR is still controversial in literature. The vasculature in retropubic space of Retzius has already been well studied. In very old studies, extrapelvic branches rooted from obturator artery defined as "anomalous" [16]. Darmanis et al. [4] reported three different anatomical structures crossing superior pubic ramus on posterior surface, arterial CMOR, venous CMOR and aberrant obturator artery. But, they preferred to keep the old definition of CMOR. According to that, CMOR is an anastomosis between obturator and external iliac or inferior epigastric vessels [4]. As seen, the aberrant obturator vessels have been excluded. According to us, the name of CMOR, in other words the Crown of Death, reveals the potential risk of bleeding depending on a surgical manipulation [15]. It is an anatomical term that reflects a clinical situation rather than an anatomical structure. Therefore, any identifiable vascular structure (arterial and/or venous, anastomosing or not) crossing the superior pubic ramus should be named as

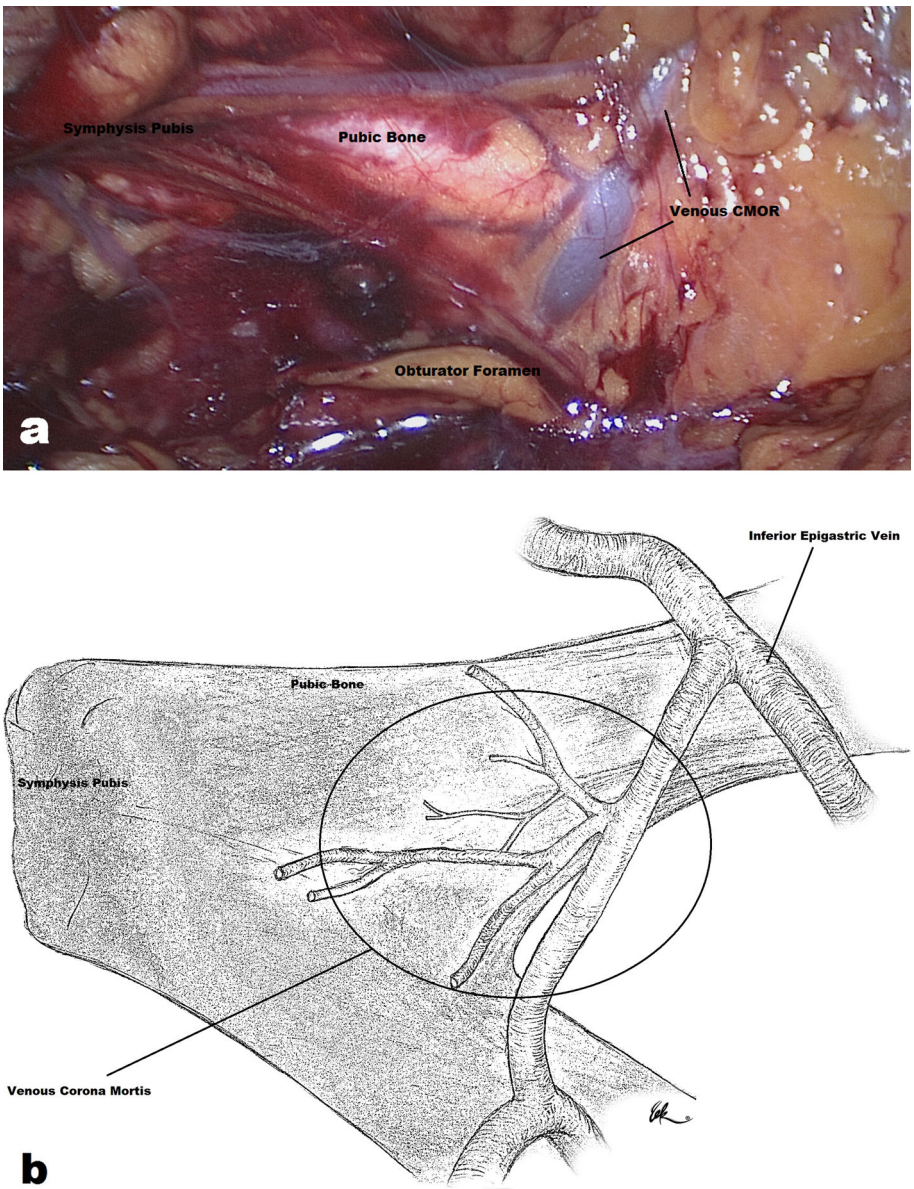

Fig. 4 **a**. Posterior view of right inguinal area under the pressure of 10 mmHg. A large venous corona mortis (CMOR) was visible under this relatively low pressure. **b**. Illustration of the **a**

Table 1 Distribution of arterial structures

Parameter	Number	%
Total number of cases	321	
Total number of hemipelvises	398	
Thick (≥2 mm) arterial anastomosis	22	5.5
Thin (<2 mm) arterial anastomosis	91	22.8
Total number of the arterial corona mortis	113	28.4
Pubic branch of inferior epigastric artery	66	16.6
Total number of arterial structure	179	45.0
Injury of the arterial corona mortis	6	1.5

CMOR due to the same localization and the similar risk of damage and bleeding. From this perspective, we thought that the aberrant obturator artery is not different from arterial CMOR. Instead, we classified the arteries as thin or thick like Rusu et al. [7]. They also used the identification of vessels according to their thickness. According to Colborn et al. [18] the "circle of death" is formed by anastomosis of an aberrant obturator artery (or vein), arising from the external iliac or inferior epigastric vessel, with a normal obturator vessel arising from the internal iliac vessel. As seen, Colborn [18] were not use the aberrant obturator artery as a different structure from arterial CMOR. Likewise, Rusu et al. [7] termed CMOR 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.

The incidence of arterial CMOR was 28.4 % in this study. In previous studies, a wide range of incidences have

been reported; 8–65 % [1–5, 7, 11] for arterial CMOR and 17–60 % [1–4, 7, 11] for venous CMOR. The variation in rates can be associated with the differences in the definition of CMOR.

Injury of CMOR by a tack (which is a fixator like a screw in shape and made from titanium) during TEP hernioplasty have been reported previously [12, 13]. Therefore, to identify the probable locations of CMOR is especially important for surgeons related the laparoscopic henioplasty. The distance from symphysis pubis to CMOR has been measured as 21–90 mm for both arterial and venous CMOR, in previous series [1, 19, 20]. In our cases, we could not measure it, because it was so difficult to provide precise measurement due to two-dimensional vision of the scope. But before application of tacker we saw the vessel free area on the first part of Cooper's ligament. Based on this visual finding and the knowledge of literature, we performed the fixation of mesh safely in great majority of the cases.

In this study, injury of arterial CMOR was seen in six cases (1.5 %). Although, it is generally accepted that vasculature overlying pubic bone are at risk of injury during TEP hernia repair [3], there was no sufficient data in literature about the injury of CMOR. We found only one case report presenting CMOR injury during tack stapling in TEP procedure [13]. This study provides the most comprehensive data about this issue. All of injured vessels by tack stapling were thin (<2 mm) arterial anastomoses. We saw that the small caliber arteries are prone to be injured due to the insufficient visualization despite magnifying scope.

The major limitation of the study was lack of detailed data about venous CMOR. During laparoscopic surgery, to provide a workspace in preperitoneal area, 14 mmHg of CO_2 was given through the port. We thought that, the pressure was much higher than in small venous structures. In the majority of the cases in this study, we worked under this high pressure. However, in the last few cases, we observed that when we decreased the pressure from 14 to 10 mmHg, venous structures became visible (Fig. 3). This revealed that the veins are collapsed under high pressure (14 mmHg), seen like a thin white band on Cooper's ligament which is also white in color, and became unidentifiable even under magnified view. Additionally, the origins of vessels or obturator foramen were not explored due to the risk of bleeding. Therefore, it is not possible to obtain reliable data about venous CMOR. Contrarily, Lau et al. [3] reported the incidence of venous CMOR as 27 % in the study performed on living patients during TEP procedure. According to us, the probable cause of the difference between two studies was the pressure of CO_2 in the workspace, 10 vs 14 mmHg. The great majority (89 hemipelvises, 82 %) of arterial CMOR was <2 mm in this study. In previous studies, mean thickness of arterial CMOR was reported as 3 mm [11] in the range of 2–4.2 mm [21]. From surgical perspective, the thickness is important for visibility of the vessels. In conventional surgery, it can be possible to miss the vessels smaller than 2 mm in diameter. In laparoscopic approaches, visibility was better due to magnification of the scope. Therefore, under a careful glance, arterial CMOR can be visible and protected.

On the posterior surface of superior pubic ramus, there is another arterial structure which is pubic branch of IEA. It originates from IEA and runs parallel to superior border of pubic ramus (Fig. 2). In this study, 65 hemipelvises (16.6 %) had pubic branch of IEA without an aberrant obturator artery. The injury of pubic branch of IEA during laparoscopic hernioplasty has not been reported. But the injury of it after trauma can be life-threatening [22, 23]. Therefore, it should not be ignored during laparoscopic hernioplasty.

In literature, most of the studies have been performed on cadavers. In these studies, authors have an advantage of tactile examination on anatomical structures with three-dimensional vision without a risk of damage or bleeding. We thought that clinical meaning of these anatomical structures is much more important for surgeons who were studying on living patients. This study provides most comprehensive in vivo data about CMOR. In laparoscopic surgery, the scope provides two-dimensional vision which is a disadvantage for examination, but it also provides detailed information about anatomical structures due to the magnifying property in a living patient.

In conclusion, the incidence of arterial CMOR was 28.4 % in this study. When the presence of pubic branch of IEA is added, the probability to encounter with an arterial structure on posterior pubic surface increases to 45.0 %. Therefore, during TEP hernia repair, the tack should be stapled as much as close to symphysis pubis on Cooper's ligament that would protect the injury of CMOR. Despite the precautions, the incidence of arterial CMOR injury was 1.5 % in this study. Small caliber arteries (<2 mm) are more prone to be injured during TEP hernia repair. To explore venous structures properly, pressure in workspace should be kept as low as possible.

Acknowledgments The abstract has been presented as a poster presentation in 12th Congress of Turkish National Endoscopic Laparoscopic Surgery, April, 22th–26th, 2015, Antalya, Turkey. We offer our special thanks to Mr. Yunus Emre Kinaci for his kind support to our study with excellent drawings.

Compliance with ethical standards

Conflict of interests The authors declared that they have no conflict of interests.

References

1. Okcu G, Erkan S, Yercan HS, Ozic U (2004) The incidence and location of corona mortis: a study on 75 cadavers. Acta Orthop Scand 75:53–55. doi:10.1080/00016470410001708100
2. Berberoğlu M, Uz A, Ozmen MM, Bozkurt MC, Erkuran C, Taner S, Tekin A, Tekdemir I (2001) Corona mortis: an anatomic study in seven cadavers and an endoscopic study in 28 patients. Surg Endosc 15:72–75
3. Lau H, Lee F (2003) A prospective endoscopic study of retropubic vascular anatomy in 121 patients undergoing endoscopic extraperitoneal inguinal hernioplasty. Surg Endosc 17:1376–1379. doi:10.1007/s00464-003-8800-y
4. Darmanis S, Lewis A, Mansoor A, Bircher M (2007) Corona mortis: an anatomical study with clinical implications in approaches to the pelvis and acetabulum. Clin Anat 20:433–439. doi:10.1002/ca.20390
5. Sarikcioglu L, Sindel M, Akyildiz F, Gur S (2003) Anastomotic vessels in the retropubic region: corona mortis. Folia Morphol (Warsz) 62:179–182
6. Pellegrino A, Damiani GR, Marco S, Ciro S, Cofelice V, Rosati F (2014) Corona mortis exposition during laparoscopic procedure for gynecological malignancies. Updates Surg 66:65–68. doi:10.1007/s13304-013-0245-9
7. Rusu MC, Cergan R, Motoc AG, Folescu R, Pop E (2010) Anatomical considerations on the corona mortis. Surg Radiol Anat 32:17–24. doi:10.1007/s00276-009-0534-7
8. Kong WM, Sun CK, Tsai IT (2012) Delayed presentation of hypovolemic shock after a simple pubic ramus fracture. Am J Emerg Med 30:2090.1–4. doi:10.1016/j.ajem.2011.12.030
9. Garrido-Gómez J, Pena-Rodríguez C, Martín-Noguerol T, Hernández-Cortes P (2012) Corona mortis artery avulsion due to a stable pubic ramus fracture. Orthopedics 35:80–82. doi:10.3928/01477447-20111122-25
10. Kacra BK, Arazi M, Cicekcibasi AE, Büyükmumcu M, Demirci S (2011) Modified medial Stoppa approach for acetabular fractures: an anatomic study. J Trauma 71:1340–1344. doi:10.1097/TA.0b013e3182092e8b
11. Stavropoulou-Deli A, Anagnostopoulou S (2013) Corona mortis: anatomical data and clinical considerations. Aust N Z J Obstet Gynaecol 53:283–286. doi:10.1111/ajo.12076
12. Ramser M, Messmer AS, Zbinden I, Von Holzen U, Nebiker CA (2014) Incarcerated obturator hernia-laparoscopic repair with intraoperative view of the corona mortis. J Surg Case Rep 25:2014. doi:10.1093/jscr/rju081
13. Moreno-Egea A, Paredes PG, Perello JM, Campillo-Soto A, Baena EG, Muñoz JR, Aguayo-Albasini JL (2010) Vascular injury by tacks during totally extraperitoneal endoscopic inguinal hernioplasty. Surg Laparosc Endosc Percutan Tech 20:129–131. doi:10.1097/SLE.0b013e3181df22a8
14. Poelman MM, van den Heuvel B, Deelder JD, Abis GS, Beudeker N, Bittner RR, Campanelli G, van Dam D, Dwars BJ, Eker HH, Fingerhut A, Khatkov I, Koeckerling F, Kukleta JF, Miserez M, Montgomery A, Munoz Brands RM, Morales Conde S, Muysoms FE, Soltes M, Tromp W, Yavuz Y, Bonjer HJ (2013) EAES consensus development conference on endoscopic repair of groin hernias. Surg Endosc 27:3505–3519. doi:10.1007/s00464-013-3001-9
15. Ates M, Dirican A, Ozgor D, Gonultas F, Isik B (2012) Conversion to Stoppa procedure in laparoscopic totally extraperitoneal inguinal hernia repair. JSLS 16:250–254. doi:10.4293/108680812X13427982376347
16. Pick JW, Anson BJ, Ashley FL (1942) The origin of the obturator artery: a study of 640 body-halves. Am J Anat 70:317–343
17. Gilroy AM, Hermey DC, DiBenedetto LM, Marks SC Jr, Page DW, Lei QF (1997) Variability of the obturator vessels. Clin Anat 10:328–332. doi:10.1002/(SICI)1098-2353
18. Colborn GL, Skandalakis JE (1998) Laparoscopic inguinal anatomy. Hernia 2:179–191
19. Karakurt L, Karaca I, Yilmaz E, Burma O, Serin E (2002) Corona mortis: incidence and location. Arch Orthop Trauma Surg 122:163–164. doi:10.1007/s004020100341
20. Tornetta P 3rd, Hochwald N, Levine R (1996) Corona mortis. Incidence and location. Clin Orthop Relat Res 329:97–101
21. Hong HX, Pan ZJ, Chen X, Huang ZJ (2004) An anatomical study of corona mortis and its clinical significance. Chin J Traumatol 7:165–169
22. Lu CK, Lee YC, Sun PL, Liang CL, Liliang PC (2010) Life-threatening bleeding from the pubic branch of the inferior epigastric artery after pubic ramus fracture. Hong Kong J Emerg Med 17:372–376
23. Meyers TJ, Smith WR, Ferrari JD, Morgan SJ, Franciose RJ, Echeverri JA (2000) Avulsion of the pubic branch of the inferior epigastric artery: a cause of hemodynamic instability in minimally displaced fractures of the pubic rami. J Trauma 49:750–753