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Case series and a systematic review concerning the level of the aortic bifurcation

Short title: Study of aortic bifurcation level

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Abstract

Background: Aim of this study is to present the level of aortic bifurcation in a sample of Greek origin (case series) and to perform an up-to-date systematic review in the existing literature.

Materials and methods: Seventy-six formalin-fixed adult cadavers were dissected and studied in order to research the level of aortic bifurcation. Additionally, PUBMED and Google Scholar databases were searched for eligible articles concerning the level of aortic bifurcation for the period up to February 2020.

Results: The mean level of aortic bifurcation according to our case series was the lower third of the L4 vertebral body (21/76, 27.6%). The level of aortic bifurcation ranged between the lower third of the L3 vertebral body and the lower third of the L5 body. No statistically significant correlation was found between the two sexes. The systematic review of the literature revealed 31 articles which were considered eligible and a total number of 3537 specimens was retracted. According to the recorded findings the most common mean level of aortic bifurcation was the body of L4 vertebra (1495/3537 cases, 42.2%), while the range of aortic bifurcation was described to occur from upper third of L3 vertebrae to the upper third of the S1 vertebrae in the 52.8% of the cases (1866/3537).

Conclusions: The mean level of AA corresponds to the body of L4 and presents a great range (form L3U to S1U). Knowledge of the mean level of aortic bifurcation and its probable

ranges is of great significance for interventional radiologists and especially vascular surgeons that deal with aneurism proximal to the aortic bifurcation.

Key words: aorta, intervertebral discs, lumbar vertebra, bifurcation, anatomy

INTRODUCTION

The aorta (or arteria magna) commences at the upper part of the left ventricle of the heart and after following a short ascending course, it forms the arcus aortae over the left lung's root and then follows a descending trajectory within the thorax as thoracic aorta. After passing through the aortic opening of the diaphragm, at the level of the 12th thoracic vertebra, it is considered as the abdominal aorta (AA) [22,31,32].

Inside the abdominal cavity the AA terminates its course usually at the left side of the lower border of the 4th lumbar vertebra (L4), where it bifurcates into the right and left common iliac arteries. The width of the aorta just after passing through the diaphragm is considerably larger than the corresponding one at the level of its bifurcation [39].

According to the available literature, most commonly, aortic bifurcation occurs at the lower level of the L4 [6, 22], with a range which varies from the level of the L2 to the level of the upper third of the first sacral vertebra (S1) [6, 22]. However, AA tends to bifurcate lower than higher [6]. Additionally, it seems that in older persons, osteoporosis and intervertebral disc degeneration lead to a caudal shift of the aortic bifurcation [21, 32].

The purpose of the present study is twofold:

1) To present the level of aortic bifurcation in a sample of Caucasian origin (case series).

2) To perform an up-to-date systematic review concerning the level of aortic bifurcation in the available literature.

MATERIALS AND METHODS

Design of the case series

Seventy-six formalin-fixed adult human cadavers of Caucasian (Greek) origin, of which 39 were males and 37 females, were dissected for educational and research purposes at the Anatomy Department of the Medical School of Athens. All the cadavers derived from body donation with informed consent [27], written and signed with signature authentication by the donator himself. The authors retained approval for the present research's protocol from the ethics committee of our institution. The age of the cadavers ranged between 39 and 98 years (average age 75.4 years, SD=±11.23, SE=1.288). In every one cadaver dissected, we identified and revealed the abdominal aorta (AA) and its branches according to the Clemente's Anatomy Dissector [10].

The level of the AA bifurcation was measured in relation to the bodies of the lumbar vertebrae and the intervertebral discs. The bodies of the vertebrae were divided into upper, middle and lower thirds.

Statistical analysis

All the measurements were recorded in the form of tables and then subjected to statistical analysis in order to calculate the average, maximum and minimum value. For comparing continuous variables, the t-test was applied and for nominal variables the x^2 test. All the statistical analysis was performed by SPSS 15.0.

Design of the systematic review

Study Design

The present study was developed according to PRISMA guidelines, following current guidelines on conducting systematic reviews and meta-analysis of anatomical studies [17]. For the purpose of the systematic review, PUBMED and Google Scholar electronic databases were searched for eligible articles for the period up to February 2020. No publication year restrictions were imposed. The following search terms were used: level of aortic bifurcation OR level of abdominal aorta bifurcation OR aortic bifurcation with lumbar vertebrae. The references of all the articles which were considered eligible were also thoroughly checked.

Inclusion criteria

Only original research articles examining the level of aortic bifurcation in relation to the bodies of the lumbar vertebrae in a human population sample (cadaveric or clinical study) and written in English or French were selected to be included to this systematic review. Single case reports and studies with overlapping populations were excluded. No limitations concerning race, age, sex or journal were imposed. Any type of unpublished material was excluded.

Eligibility assessment

Three independent reviewers (E.P., G.T. and V.P.) checked the studies which were retrieved for eligibility. Papers which did not meet eligibility criteria, duplicated studies or studies containing incomplete or irrelevant data were excluded. Eligible studies retrieved from reference lists checking were also added. Assessment of bias was performed with anatomical quality assessment tool (AQUA) [16,17].

Data extraction

The studies considered eligible were screened by two independent reviewers (E.P. and G.T.) who extracted all the relevant data. For each study considered eligible the following parameters were collected: year of publication, type of the study (cadaveric, clinical, imaging), number of specimens, age, range and mean vertebral level of aortic bifurcation. After the evaluation of data, the results were recorded in the form of tables (Tables 1&2). The range, the mean level of bifurcation, as well as the frequency and percentage of each category were calculated.

Results

Case series

The bifurcation of AA was observed on each cadaver dissected without identifying any anatomical variation.

The mean level of AA bifurcation (21/76, 27.6%) was the lower third of the L4 vertebral body (L4L). In relation to the vertebral bodies, the level of AA bifurcation ranged between the lower third of the L3 vertebral body (L3L) and the lower third of the L5 body (L5L) (fig.1).

Both in females (32.4%, 12/37) and males (23.1%, 9/39) the mean level of bifurcation corresponded also to the lower third of the L4 body (L4L). In females the level of bifurcation ranged between the lower third of the L3 body (L3L) and the middle third of the L5 vertebral body (L5M) and in males between the L3-L4 intervertebral dick and the L5L. However, no statistically significant correlation was found between the two sexes ($p=0.521$, $p>0.05$).

The AA division levels in relation to the lumbar vertebral bodies and the relevant intervertebral discs in the total of the cadaveric specimens are depicted in figure 2 and between the sexes in figure 3.

Systematic Review

All details regarding the selection of eligible studies are presented in Figure 4 (Prisma Flow diagram). Eventually 31 articles were found eligible and were included (Table 1). Due to overlapping population, a previous study of the authors was not included [23]. Among them, fourteen were cadaveric studies [1, 2, 7, 8, 12, 13, 19, 21, 23, 31, 33-36], eight were

MRI studies [4, 5, 9, 18, 24, 26, 29, 37], four were CT studies [14, 22, 28, 30], two were CTA studies [11, 15], one MDCT study [20], one was angiographic study [38] and one was based on pelvic arteriograms [25]. Mean age or age range where included when available. Low risk of bias was detected. However, the lack of clearly defined demographic characteristics might represent a factor compromising the quality of studies.

The mean level of bifurcation and the range of the bifurcation level of the AA in relation to the bodies of the lumbar vertebrae and the intervertebral discs for each study is recorded in Table 2. In cases where the vertebral bodies were not subdivided into upper, middle and lower thirds, as in our study, only the corresponding vertebra is mentioned.

A total number of 3537 specimens resulted from the eligible studies. According to the recorded findings the most common mean level of AA bifurcation was the body of L4 vertebra (1495/3537 cases, 42.2%). In the studies were the body of the vertebra was divided in three thirds, the bifurcation most frequently occurred at upper third of L4. Considerably less frequently the mean level corresponded to L4-L5 intervertebral disc (132/3537 cases 3.7%), while the L3-L4 intervertebral disc and the body of L5 were observed as mean level, of bifurcation in only a few studies (23/3537 – 0.65% and 21/3537 – 0.59%). Concerning the range of AA bifurcation, a great variability was observed, as the bifurcation was described to occur from upper third of L3 vertebrae to the upper third of the S1 vertebrae in the 52.8% of the cases (1866/3537). The results are represented in Table 3.

DISCUSSION

Topographic anatomy of AA bifurcation is fairly important for many medical procedures as gynecology, abdominal surgery or radiology, in order to avoid complications or misdiagnosis [31]. Clinically, the umbilicus is considered to be a reliable surface landmark for the level of AA bifurcation [3]. More accurate, the level of AA bifurcation is evaluated in relation to the vertebral bodies and especially the lower lumbar ones and rarely in relation to the sacrum. Several studies have been performed and may be found in the available literature covering this field, [1, 2, 4, 5, 21-26, 7-9, 11-14, 15, 18, 19, 20, 28-31, 33-37, 38] either in cadaveric material or by the use of CT, MRI and CTA. According to the results of the present study, the bifurcation of the AA corresponds in most of the cases to the body of L4 vertebra – upper, medial or lower third (1495/3537 cases, 42.2%) and that was also the level discovered in our case-series (21/76, 27.6%). From our systematic review it occurred that the level of bifurcation presents great variation as it ranges from L3U to S1U, with the most frequent levels being between L3 and L5 (Table 3).

Kawahara et al. 1996 [19] reported that the level of termination of great vessels shifted significantly downwards with age and this observation is justified by the loss of overall height due to dehydration of intervertebral discs as well as osteoporosis in the elderly. The present case series was performed in rather aged cadavers (mean age 75.4 ±11.23years) and the level of their aortic bifurcation ranged between L3L and L5L. The studies retrieved from the systematic review showed a variable age range (Table 1). Moreover, many of them included both youngsters as older people as well [8, 9, 14, 25, 29,35, 37]. However, both range and mean level of aortic bifurcation did not seem to differ according to age. Additionally, in the two studies which were conducted exclusively in children [15, 38] a great range was also recorded (L4 to L5-S1 and L3 to L5 respectively). Nevertheless, all above mentioned facts, combined with the lack of age details in some studies [1, 2, 7, 12, 18, 22, 36] could not lead to a safe result concerning the correlation between age and level range of AA bifurcation.

The same mean level of AA bifurcation was observed in both sexes in our case series. That was also the case in the study of Molinares et al. [29], Bečulić et al. [5] and R. Goyal et al. [14], while in most of the remaining studies, details about sexes were not provided and or when present, the presence of a statistically significant difference between sexes was not discussed at all. Consequently, it seems that the level of aortic bifurcation does not differ according to gender. Moreover, is worth to mention that Bečulić et al. [5] concluded in their study that the level of AA bifurcation was independent on gender, height or BMI.

Concerning the limitations of the present study, the most important was the lack of demographic characteristics of most of the studies. The majority did not provide detailed data about age and gender. Another limitation was the fact that there was a wide age range and that some studies consisted of live patients while others were conducted on cadavers. Radiographic studies may also have limitations in detecting the level of aortic bifurcation. Nevertheless, not important differences have been observed between the two types of studies.

Knowledge of the exact level of AA bifurcation is important for the planning of a great number of laparoscopic, transcatheter arterial chemoembolization and radioembolization procedures, as well in view of surgery in the area involved as it will minimize the risk of injury and complications [2, 29, 14]. The fact that the mean level of bifurcation is at L4 vertebra and the range is over S1, is a helpful information in the planning of approach during surgery, especially when the area of operation involves L4-L5 [14, 31]. Another field of medicine where the familiarity with the level of AA bifurcation is necessary is radiation therapy planning [14, 29]. Finally, it could help in the identification of the vertebral level in imaging [14, 29].

CONCLUSIONS

Knowledge of the mean level of AA bifurcation and its probable ranges is important for a number of surgical and radiologic procedures. Our systematic review, combined with a case series study concluded that the mean level of AA corresponds to the body of L4 and presents a great range (form L3U to S1U). Aging might cause a caudal swift of AA, nevertheless different ranges and low levels might occur in any age. Finally, there is no indication of a different level according to gender.

References

1. Anson BJ, McVay CB. The topographical positions and the mutual relations of the visceral branches of the abdominal aorta. A study of 100 consecutive cadavers. Anat Rec. 1936; 67:7–15.
2. Appaji AC, Kulkarni R, Balaji SP. Level of Bifurcation of Aorta and Iliocaval Confluence and Its Clinical Relevance. IOSR-JDMS. 2014;13(7):56-60
3. Attwell L, Rosen S, Upadhyay B, Gogalniceanu P. The umbilicus: a reliable surface landmark for the aortic bifurcation? Surg Radiol Anat. 2015;37(10):1239–1242. doi:10.1007/s00276-015-1500-1
4. Barrey C, Ene B, Louis-Tisserand G, Montagna P, Perrin G, Simon E. Vascular anatomy in the lumbar spine investigated by three-dimensional computed tomography angiography: the concept of vascular window. World Neurosurg. 2013;79(5-6):784–791. doi:10.1016/j.wneu.2012.03.019
5. Bečulić H, Sladojević I, Jusić A, Skomorac R, Imamović M, Efendić A. Morphometric study of the anatomic relationship between large retroperitoneal blood vessels and intervertebral discs of the distal segment of the lumbar spine: a clinical significance. Med Glas (Zenica), 2019;16(2):260-264.
6. Bergman RA, Afifi AK, Miyauchi R. Illustrated Encyclopedia of Human Anatomic Variation. last revised: 2006. http://www.anatomyatlases.org/AnatomicVariants/AnatomyHP.shtml
7. Butoi G, Iliescu DM, Baz R, Bordei P. Morphology of the terminal aorta. ARS Medica Tomitana - 2013; 2(73): 61 – 66
8. Cauldwell EW, Anson BJ. The visceral branches of the abdominal aorta: Topographical relationships. Am J Anat. 1943; 73:27–57.
9. Chithriki M, Jaibaji M, Steele RD. The anatomical relationship of the aortic bifurcation to the lumbar vertebrae: a MRI study. Surg Radiol Anat. 2002; 24:308-12.
10. Clemente C, Clemente C. Clemente's anatomy dissector. Philadelphia, Pa.: Lippincott Williams & Wilkins; 2010: 131-160
11. Datta J C, Janssen ME, Beckham R, & Ponce C. The Use of Computed Tomography Angiography to Define the Prevertebral Vascular Anatomy Prior to Anterior Lumbar Procedures. Spine. 2007;32(1): 113–119.

12. Deswal A, Tamang BK, Bala A. Study of aortic- common iliac bifurcation and its clinical significance. J Clin Diagn Res. 2014;8(7):AC06–AC8. doi:10.7860/JCDR/2014/8767.4559
13. George R. Topography of the unpaired visceral branches of the abdominal aorta. J Anat. 1935; 69:96–92.
14. Goyal R, Aggarwal A, Gupta T, et al. Reappraisal of the classical abdominal anatomical landmarks using in vivo computerized tomography imaging. Surg Radiol Anat. 2020;42(4):417–428. doi:10.1007/s00276-019-02326-4
15. Gregory LS, McGifford OJ, Jones LV. Differential growth patterns of the abdominal aorta and vertebrae during childhood. Clin Anat. 2019;32(6):783–793. doi:10.1002/ca.23400
16. Henry BM, Tomaszewski KA, Ramakrishnan PK, et al. Development of the anatomical quality assessment (AQUA) tool for the quality assessment of anatomical studies included in meta-analyses and systematic reviews. *Clin Anat*. 2017;30(1):6-13. doi:10.1002/ca.22799.
17. Henry BM, Tomaszewski KA, Walocha JA. Methods of Evidence-Based Anatomy: a guide to conducting systematic reviews and meta-analysis of anatomical studies. *Ann Anat*. 2016;205:16-21. doi:10.1016/j.aanat.2015.12.002
18. Inamasu J, Kim DH, Logan L. Three-dimensional computed tomographic anatomy of the abdominal great vessels pertinent to L4-L5 anterior lumbarinterbody fusion. Minim Invasive Neurosurg. 2005; 48:127-131.
19. Kawahara N, Tomita K, Baba H, Toribatake Y, Fujita T, Mizuno K, Tanaka S. Cadaveric vascular anatomy for total en bloc spondylectomy in malignantvertebral tumors. Spine. 1996; 21:1401-1407.
20. Keskinoz EN, Salbacak A, Akin D, Kabakci ADA, Yilmaz MT, Cicekcibasi AE, Ozbek O. Morphometric analysis of the inferior vena cava related to lumbar vertebra and the aortic bifurcation on multidetector computed tomography (MDCT). Int J Morphol. 2016; 34:620-7.
21. Khamanarong K, Sae-Jung S, Supa-Adirek C, Teerakul S, Prachaney P. Aortic bifurcation: a cadaveric study of its relationship to the spine. J Med Assoc Thai. 2009; 92:47-49.
22. Kornreich L, Hadar H, Sulkes J, Gornish M, Ackerman J, Gadoth N. Effect of normal ageing on the sites of aortic bifurcation and inferior vena cava confluence: a CT study. Surg Radiol Anat 1997;20: 63–68.
23. Lakchayapakorn K, Siriprakarn Y. Anatomical variations of the position of the aortic bifurcation, iliocava junction and iliac veins in relation to the lumbar vertebra. J Med Assoc Thai. 2008;91: 1564-1570.
24. Lee CH, Seo BK, Choi YC, Shin HJ, Park JH, Jeon HJ, Kim KA, Park CM, Kim BH. Using MRI to evaluate anatomic significance of aortic bifurcation, right renal artery, and conus medullaris when locating lumbar vertebral segments. AJR Am J Roentgenol. 2004; 182:1295-1300.
25. Lerona PT, Tewfik HH. Bifurcation level of the aorta: landmark for pelvic irradiation. Radiology. 1975;115(3):735. doi:10.1148/15.3.735.
26. Marchi L, Oliveira L, Amaral R, Fortti F, Pimenta L, Abdala N. Morphometric study of the areolar space between the great vessels and the lumbar spine. Coluna/Columna 2015; 14:271- 5.
27. McHanwell S, Brenner E, Chirculescu ARM, Drukker J, van Mameren H, Mazzotti G, Pais D, Paulsen F, Plaisant O, Caillaud M, Laforêt E, Riederer BM, Sanudo JR, Bueno-Lopez JL, Donate F, Sprumont P, Teofilovski-Parapid G, Moxham BJ. The

legal and ethical framework governing Body Donation in Europe - A review of current practice and recommendations for good practice. Eur J Anat. 2008; 12:1-24.
28. Mirjalili SA, McFadden SL, Buckenham T, Stringer MD. A reappraisal of adult abdominal surface anatomy. Clin Anat. 2012;25(7):844–850. doi:10.1002/ca.22119
29. Molinares DM, Davis TT, Fung DA. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs: an MRI study. J Neurosurg Spine. 2016;24(2):248–255. doi:10.3171/2015.3.SPINE13976
30. Myung-Sang M. Anatomical Location, Running Pattern, and Bifurcation Level of Abdominal Aorta over the Lumbosacral Spine: Computed Tomography Angiographic Study. J Spinal Surg. 2017;4(3):97-101
31. Ogeng'o J, Olabu B, Ongeti K, Misiani M, Waisako B, Loyal P. Topography of Aortic Bifurcation in a Black Kenyan Population. Anat J Africa. 2014;3(2).
32. Panagouli E, Lolis E, Venieratos D. A morphometric study concerning the branching points of the main arteries in humans: relationships and correlations. Ann Anat. 2011;193(2):86–99. doi:10.1016/j.aanat.2010.10.009
33. Pennington N, Soames RW. The anterior visceral branches of the abdominal aorta and their relationship to the renal arteries. Surg Radiol Anat. 2005; 27:395-403.
34. Pirró N, Ciampi D, Champsaur P, Di Marino V. The anatomical relationship of the iliocava junction to the lumbosacral spine and the aortic bifurcation. Surg Radiol Anat. 2005;27(2):137–141. doi:10.1007/s00276-004-0301-8
35. Prakash, Mokhasi V, Rajini T, Shashirekha M. The abdominal aorta and its branches: anatomical variations and clinical implications. Folia Morphol (Warsz). 2011;70(4):282–286.
36. Sharma M, Sharma T, Singh R. Variations in the aortic - common iliac bifurcation in man - a cadaveric study. Nat J ClinAnat. 2013; 02(02): 056-060
37. Vaccaro AR, Kepler CK, Rihn JA, et al. Anatomical relationships of the anterior blood vessels to the lower lumbar intervertebral discs: analysis based on magnetic resonance imaging of patients in the prone position. J Bone Joint Surg Am. 2012;94(12):1088–1094. doi:10.2106/JBJS.K.00671
38. Watt I, Park WM. The abdominal aorta in spina bifida cystica. Clin Radiol. 1978;29(1):63–68. doi:10.1016/s0009-9260(78)80167-6
39. White HJ, Bordes S, Borger J. Anatomy, Abdomen and Pelvis, Aorta. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; 2020.

Table 1. Eligible studies

Authors	**Type of studies**	**n**	**Age**
George 1935	Cadaveric study	105	>17 years
Anson&McVay 1936	Cadaveric study	100	-
Cauldwell & Anson 1943	Cadaveric study	294	18 to 78 years
Lerona & Tewfik 1975	Pelvic arteriograms	100	15 to 82 years
Watt & Park 1978	Angiographic study	9	2 to 13 years
Kawahara et al. 1996	Cadaveric study	21	75 years

Kornreich et al. 1997	CT study	180	-
Chithriki et al. 2002	MRI study	441	15 to 95 years
Lee et al. 2004	MRI study	210	67.3 ± 0.8 years
Inamasu et al. 2005	MRI study	100	-
Pennington &Soames 2005	Cadaveric study	15	67 to 95 years
Pirro et al. 2005	Cadaveric study	42	81±8 years
Datta et al. 2007	CTA study	76	
Lakchayapakorn & Siriprakarn 2008	Cadaveric study	65	73 ± 10 years
Khamanarong et al. 2009	Cadaveric study	187	67.3 ± 0.8 years
Prakash et al. 2011	Cadaveric study	54	16 to 74 years
Mirjalili et al. 2012	CT study	108	60± 17 years (18 to 97 years)
Vaccaro et al. 2012	MRI study	30	41 years (19-89 years)
Barrey et al. 2013	MRI study	146	46 ± 12 years
Butoi et al. 2013	Cadaveric study	148	-
Sharma at al. 2013	Cadaveric study	35	-
Deswal et al. 2014	Cadaveric study	25	-
Ashwini et al. 2014	Cadaveric study	40	-
Ogeng'o et al. 2014	Cadaveric study	106	27 to 81 years
Marchi et al. 2015	MRI study	108	-
Keskinoz et al. 2016	MDCT study	200	50 to 84 years
Molinares et al. 2016	MRI study	100	57.4 years (22 to 88 years).
Myung-Sang 2017	CT study	48	30 to 90 years
Gregory et al. 2019	CTA study	232	neonate to 19 years
Bečulić et al. 2019	MRI study	40	53.7 years (26 to 69 years)
Goyal et al. 2019	CT study	100	43.78 ± 13.1 years (19 to 70 years)

Table 2. Mean level and range of aorta bifurcation related to vertebral bodies

Authors	**n**	**Level**	**Range**
George 1935	105	L4L (25/105)	L3L to L5L
Anson&McVay 1936	100	L4M (32/100)	L3M to L5M
Cauldwell & Anson 1943	294	L4-L5 (83/294)	L3M to L5L
Lerona & Tewfik 1975	100	L4L (35/100)	L4U to L5L
Watt & Park 1978	9	L4 (5/9)	L4 to L5-S1
Kawahara et al. 1996	21	L4-L5 (9/21)	L3 to L5
Kornreich et al. 1997	180	L4U (62/180)	L3U to S1U
Chithriki et al. 2002	441	L4 (295/441)	L3U to L5M
Lee et al. 2004	210	L4U (94/210)	L3L to L5U
Inamasu et al. 2005	100	L4 (55/100)	L3 to L5
Pennington &Soames 2005	15	L4L *(6/15)*	L4U to S1U
Pirro et al. 2005	42	L5 (21/42)	L3 to S1
Datta et al. 2007	76	L4 (39/76)	L3 to S1
Lakchayapakorn & Siriprakarn 2008	65	L4M (41/65)	L3 to L5
Khamanarong et al. 2009	187	L4 (131/187)	L4 to L5
Prakash et al. 2011	50	L4 (27/50)	L3 to L5
Mirjalili et al. 2012	108	L4 (65/108)	L3L to L5L
Vaccaro et al. 2012	30	L4 (22/30)	L3 to L5
Barrey et al. 2013	146	L4 (93/146)	L3-L4 to L4-L5
Butoi et al. 2013	148	L4-L5 (40/148)	L3M to L5-S1
Sharma at al. 2013	35	L4 (19/35)	L3 to L5
Deswal et al. 2014	25	L4 (16/25)	L3 to L5
Ashwini et al. 2014	40	L4 (22/40)	L3 to L5-S1
Ogeng'o et al. 2014	106	L4L (41/106)	L3-L4 to L5
Marchi et al. 2015	108	L4 (56/108)	L3 to L5
Keskinoz et al. 2016	200	L4M (53/200)	L3M to L5U
Molinares et al. 2016	100	L4M (33/100)	L3L to L5L
Myung-Sang 2017	48	L3-L4 (23/48)	L3 to L5
Gregory et al. 2019	232	L4 (155/232)	L3 to L5
Bečulić et al. 2019	40	L4L (14/40)	L3M to L5-S1
Goyal et al. 2019	100	L4U(38/100)	L3U to L5U
Present series	76	L4L (21/76)	L3L to L5L
Total	**3537**	**L4 (1495/3537)**	**L3U to S1U**

Table 3. Mean and range level of abdominal aorta (AA) bifurcation according to the retrieved studies

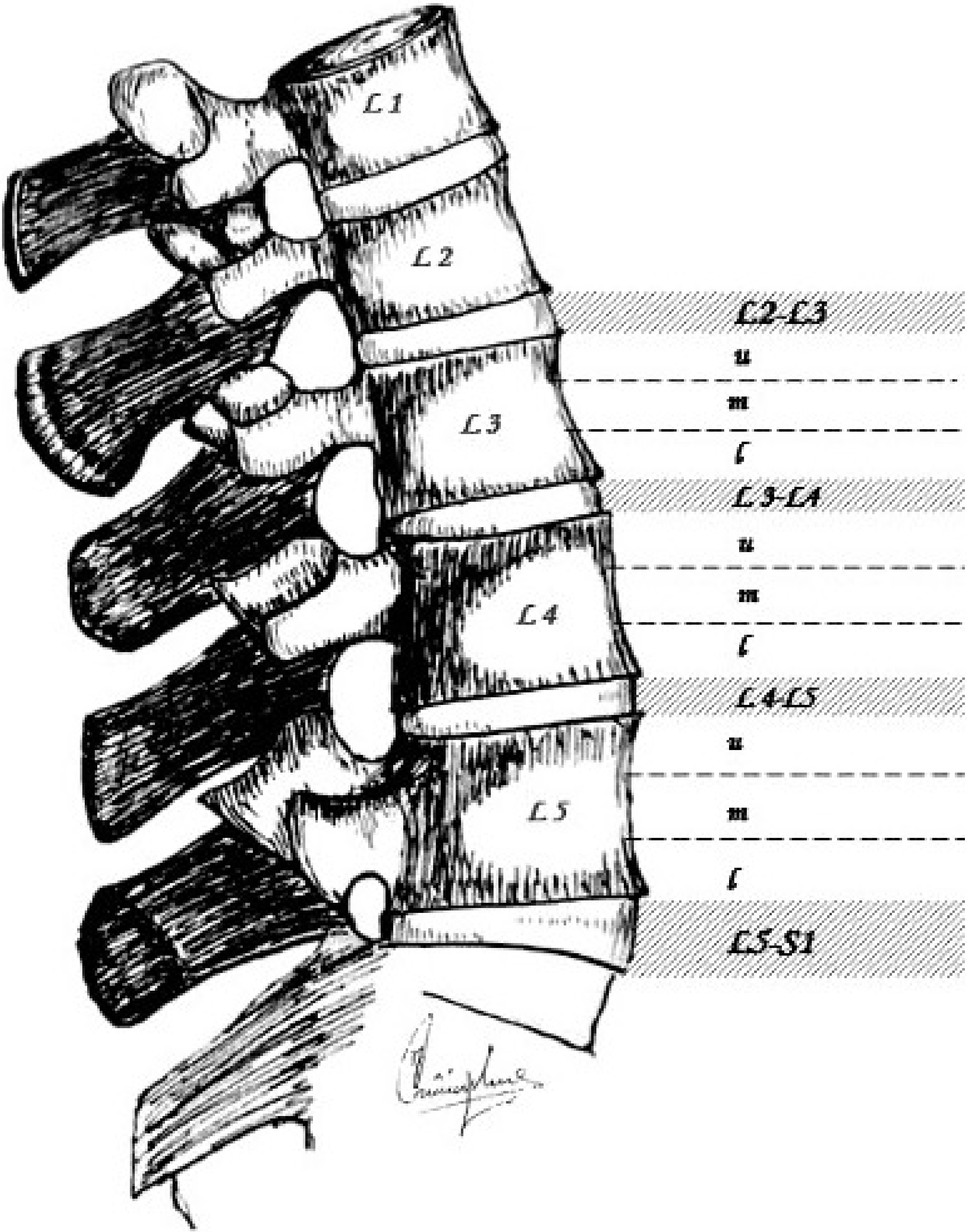
Mean level of AA bifurcation		***Range of AA bifurcation***	
• **L3-L4** **132/3537 - 3.7%**		• **L3U to S1U** 1866/3537, 52.8%	***L3 to L5*** *1286/1866* ***L4 to L5*** *121/1866* ***L4 to L5-S1*** *4/1866* ***L3 to S1*** *176/1866* ***L4 to S1*** *9/1866* ***L3-L4 to L4-L5*** *53/1866* ***L3 to L5-S1*** *152/1866* ***L3-L4 to L5*** *65/1866*
• **L4** **1495/3537, 42.2%**	○ ***L4 body*** *n=993* ○ ***L4U*** *n= 194* ○ ***L4M*** *n= 159* ○ ***L4L*** *n=149*		
• **L4-L5** **23/3537 – 0.65%**			
• **L5** **21/3537 – 0.59%**			

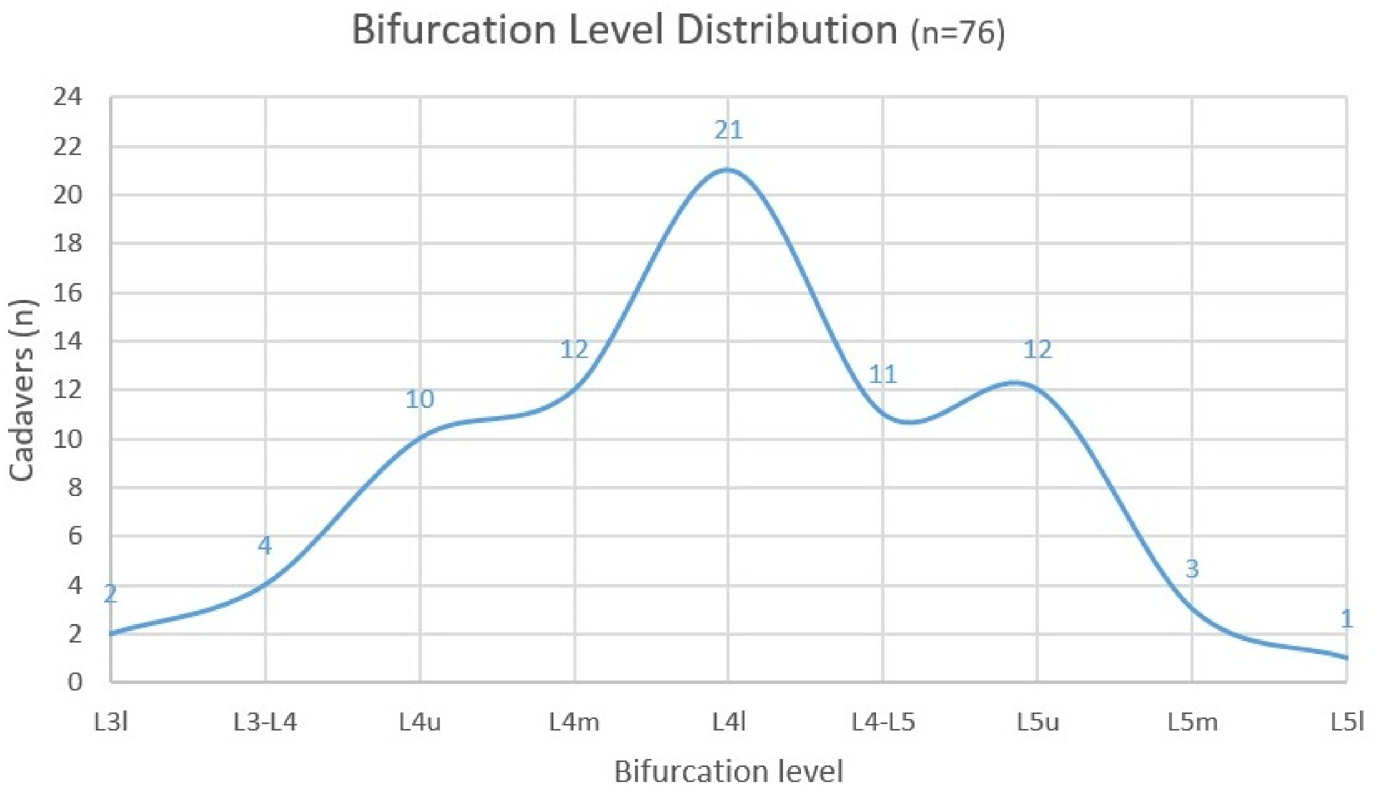
Figure 1. Ranges of the level of abdominal aorta (AA) bifurcation; U — upper; m — middle; l — lower.

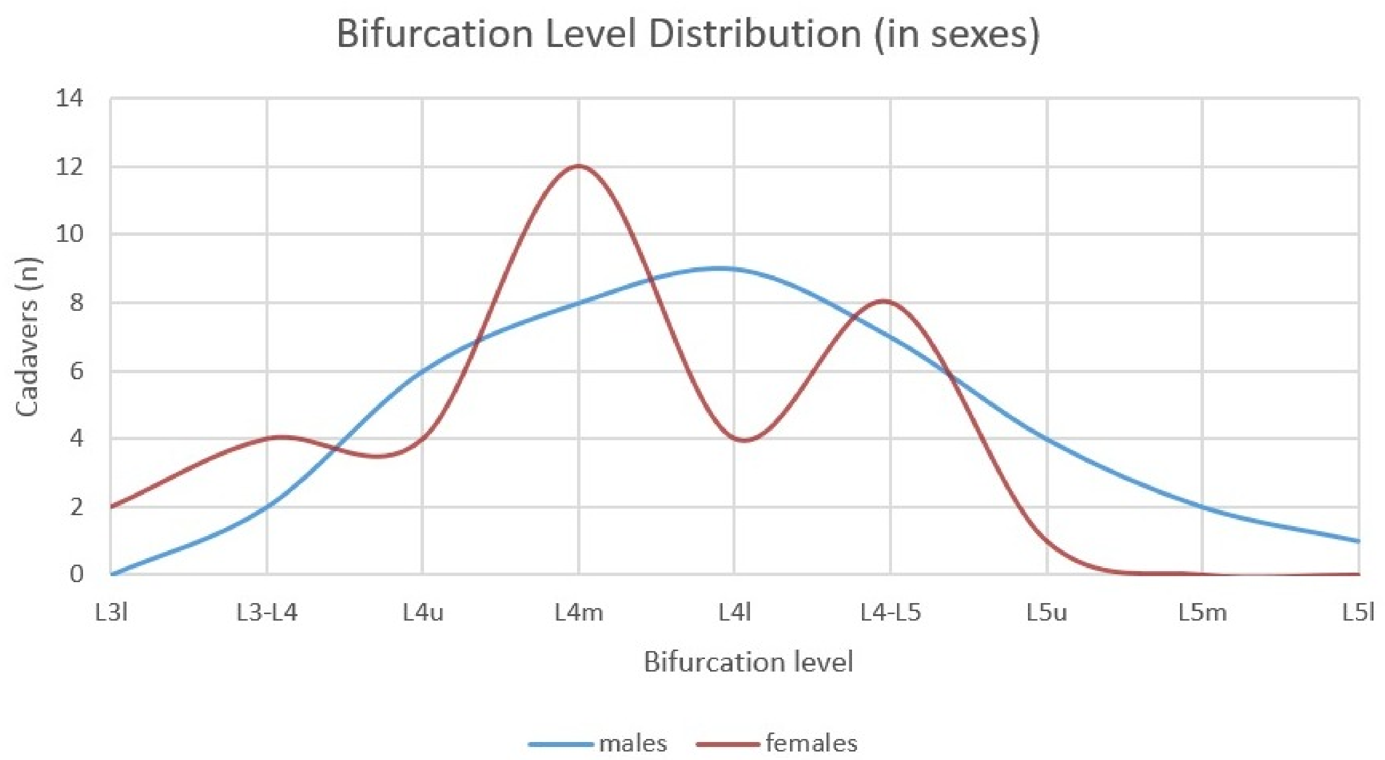
Figure 2. The abdominal aorta (AA) bifurcation levels in relation to the lumbar vertebral bodies and the relevant intervertebral discs in the total of the cadaveric specimens; U — upper; m — middle; l — lower.

Figure 3. The abdominal aorta (AA) bifurcation levels in relation to the lumbar vertebral bodies and the relevant intervertebral discs between the sexes; U — upper; m — middle; l — lower.

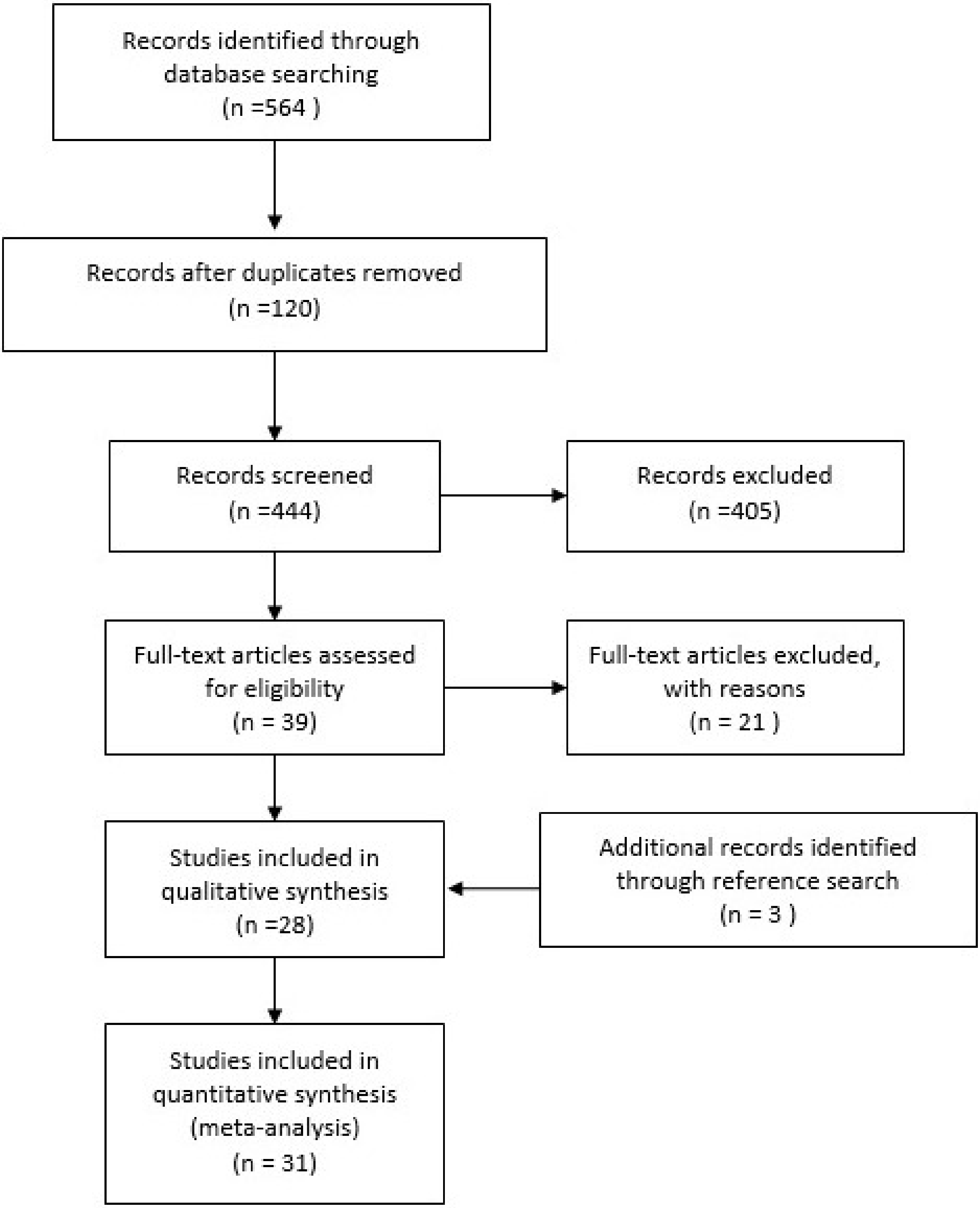
Figure 4. Flow diagram of the studies (according to prisma guidelines); the diagram describes the steps followed during the selection of the eligible studies.


L1
L2
L3
L4
L5
L2-L3
u
m
l
L3-L4
u
m
l
L4-L5
u
m
l
L5-S1


Bifurcation Level Distribution (n=76)
Cadavers (n)
Bifurcation level
0
2
4
6
8
10
12
14
16
18
20
22
24
L3l
L3-L4
L4u
L4m
L4l
L4-L5
L5u
L5m
L5l
2
4
10
12
21
11
12
3
1



Bifurcation Level Distribution (in sexes)
14
12
10
8
6
4
2
0
Cadavers (n)
L3l
L3-L4
L4u
L4m
L4l
L4-L5
L5u
L5m
L5l
Bifurcation level
males
females


Records identified through database searching (n =564)
Records after duplicates removed (n =120)
Records screened (n =444)
Records excluded (n =405)
Full-text articles assessed for eligibility (n = 39)
Full-text articles excluded, with reasons (n = 21)
Studies included in qualitative synthesis (n =28)
Additional records identified through reference search (n = 3)
Studies included in quantitative synthesis (meta-analysis) (n = 31)