The relation of vertebral artery occlusion and intravertebral cleft: a prospective magnetic resonance angiography study

Tianyu Zhang
Peking University People's Hospital
Feng Xue
Peking University People's Hospital
Yu Kang
Peking University People's Hospital
Yanhua Wang
Peking University People's Hospital
Peixun Zhang
Peking University People's Hospital
Dianying Zhang
Peking University People's Hospital
Baoguo Jiang (jbg8178@126.com)
Peking University People's Hospital

Research Article

Keywords: Intravertebral cleft, Osteoporosis vertebral compression fracture, Magnetic resonance angiography, Segmental artery, Occlusion

Posted Date: February 23rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-237035/v1

Abstract

Purpose

To detect the relationship between the vertebral artery occlusion and the intravertebral cleft (IVC).

Methods

A prospective evaluation of the vertebral segmental artery condition from the T10 to L4 with the magnetic resonance angiography (MRA) was performed in 44 osteoporosis vertebral compression fracture (OVCF) patients. The artery condition was divided into the patency, narrow, occlusion. The lesion segmental occlusion rate (LSOR) and the total occlusion rate (TOR) was calculated. The relation of the vertebral artery occlusion and the IVC formation was assessed with the univariate analysis.

Results

LOSR was 15.34% and TOR was 15.2%. The segmental arteries of the unfractured vertebrae had higher occlusion rate in thoracolumbar levels than non-thoracolumbar levels. Neither lesion levels arteries occlusion nor the total segmental arteries occlusion was associated with the IVC.

Conclusions

Vertebral compression fracture did not lead to the segmental artery occlusion. The segmental artery occlusion more likely happened in the thoracolumbar levels. The segmental artery occlusion did not lead to the IVC.

Introduction

Osteoporosis vertebral compression fracture (OVCF) is the commonest osteoporosis fracture. Systemic treatment can always relieve the pain. However, the OVCF with intravertebral cleft (IVC) formation was always indicating a poor prognosis even after the vertebral augmentation surgery. Complications such as cement leakage [1], augmented vertebra recollapse (Fig.1 f, g) [2], and the adjacent vertebral fracture [3] were more common in IVC patients. IVC was an area of low-intensity on T1-weighted and high-intensity or low-intensity on T2-weighted MRI in fracture vertebra (Fig.1 b, c, d)[4].

The hypotheses of IVC formation were controversial. They were avascular necrosis (AVN) [5], air formation [6], biomechanics changes [7], and pseudarthrosis formation [8]. Among them, the AVN theory hypothesizes that the IVC is the sign of osteonecrosis resulted from the vascular insult, which received increasing attention from researchers [9,10].

There is growing evidence that the poor blood supply of the vertebrae leads to the IVC. Lin [9] found that the IVC was related to the adjacent vertebrae poor bone marrow perfusion identified by the dynamic contrast-enhanced magnetic resonance imaging. Kim found high artery occlusion rate in the IVC patients

by magnetic resonance angiography (MRA)[10]. Due to the lack of a control group in Kim's study, the segmental artery occlusion leading to the IVC could not be concluded. Therefore, we performed this study to elucidate the relationship between segmental artery occlusion and IVC formation (Fig.1 e).

Methods

The study was approved by the Ethics Review Committee of Peking University People's Hospital with an approval number of 2019PHB240. All the written informed consents were acquired from the patients.

Patients

We prospectively recruited 44 patients (male: female= 14: 30) with OVCF from the traumatic orthopedic department at a tertiary grade-A hospital. The patients with a long time between traumatic and surgery were tended to be included in this research. Patients with infection or malignancy were excluded from this study. The affected vertebrae were T5 in 1 patient, T9 in 4 patients, T10 in 1 patient, T11 in 3 patients, T12 in 9 patients, L1 in 14 patients, L2 in 8 patients, L3 in 1 patient, L4 in 3 patients, L5 in 2 patients. All the patients underwent the X-ray and MRA for the thoracic or lumbar spine. The subjects were divided into the IVC group and the non-IVC group according to the MRI.

Sample size calculation

For comparing the occlusion rate of compression vertebral artery between the non-IVC group and IVC group. Previous literature revealed that the occlusion rate of vertebral artery in patients with IVC was 57.8% [10]. The incidence of lumbar artery occlusion was 19%-27% [11]. Therefore, we assumed that the incidence of artery occlusion in non-IVC patient was 0.3, which is a little higher than the normal vertebral occlusion rate for the compression fracture. The incidence of artery occlusion in the IVC group was 0.6. The α was 0.05 and β was 0.2. The number of IVC group and the non-IVC group was 1:1. The calculated sample size was as follows: number of arteries in non-IVC group was 40 and IVC group was 40. [12]

Data Collection

The characteristics of the patients were age, gender, body mass index (BMI), and fracture levels. The comorbidities affecting the blood supply of the patients were recorded to reflects the blood supply condition. The vertebral avascular risk factors assessment included hypertension, diabetes mellitus, coronary heart disease, cerebral infarction, hormone usage, and smoking [13]. Each factor was regarded as 1 point and the vertebral avascular risk factor was the sum of all scores of the patient.

All data collection including the X-ray or CT, MRI, MRA results were reviewed by the double-blind method. The IVC data and vertebral occlusion condition were separately collected by two experienced surgeons. Compression rate (CR) was calculated according to previous study [1]. Fracture severity was graded as grade 1: mild (<25% collapse); grade 2: moderate to severe (>25% collapse) [14]. The diagnosis of IVC was an area of low-intensity on T1-weighted and high-intensity or low-intensity on T2-weighted MRI in fracture vertebra (Fig. 1).

There were pairs of segmental arteries of each thoracic and lumbar vertebrae except the L5 [15]. MRA covered T10 to L4 segments and corresponding arteries condition were recorded. Each vertebral artery condition was classified into patency, narrow, occlusion and was scored into 1, 0.5, 0, respectively (Fig. 2). The compression vertebral segmental artery occlusion condition was observed and recorded by an experienced surgeon twice with an interval of more than one month. The intraclass correlation efficiency in the segmental artery occlusion was 0.788 ($P < 0.001$). The vertebral artery condition from the T10 to the L4 of each patient were all recorded. The compression vertebral segmental arteries were labeled. The occlusion rate was divided into the lesion segmental occlusion rate (LSOR) and the total occlusion rate (TOR). The LSOR was the sum of both two sides of the fractured vertebral artery condition dividing the lesion segmental arteries number. The total occlusion rate was the sum of whole vertebrae (T10-L4) artery condition divided by the total artery number.

Data Analysis

The basic characteristics were compared between the IVC and non-IVC groups, including age, gender, BMI, vertebral avascular risk factors, thoracolumbar levels (T11-L2), fracture severity, preoperative compression ratio, the time before MRI, LSOR, and TOR.

Statistical Analysis

Univariate analysis was analyzed using SPSS Ver. 22.0 for Windows (IBM Corp. NY, USA). The continuous variables were analyzed with the chi-square tests. The categorical variables were analyzed with the Mann-Whitney U tests. The dichotomic variables were analyzed with the student's t-tests. $P>0.05$ was regarded as no significant difference.

Results

Total 44 patients (male: female= 14: 30) with 46 fractured vertebrae were included in this study. The mean age of the patients was 74.6 years old. Twenty-one (45.6%) of the compression vertebrae had IVC. The mean time from injury to MRI diagnosis was 21 days. There was a total of 588 vertebral arteries and the total occlusion rate was 15.2%. And there were 46 fracture levels with 92 vertebral arteries. The total segmental artery occlusion rate was 15.3% (Table 1). Among the unfractured levels, artery occlusion or narrow rate of T10 was 20.9%, T11 was 23.8%, T12 was 34.3%, L1 was 23.3%, L2 was 8.4%, L3 was 4.6%, and L4 was 8.9% (Fig.3).

There were 42 IVC vertebral fracture levels arteries and 50 non-IVC vertebral fracture levels arteries. The time from injury to MRI diagnosis had a significant difference between the IVC group and the non-IVC group ($P=0.041$). There was no significant difference in age, gender, BMI, vertebral avascular risk factors, thoracolumbar levels (T11-L2), fracture severity, preoperative compression ratio ($P>0.05$). Neither the lesion segmental occlusion rate (LSOR) nor the total occlusion rate (TOR) showed a significant difference between the IVC and non-IVC patients ($P>0.05$) (Table 2).

Discussion

IVC formation in the osteoporosis vertebral compression fracture was significantly associated with the poor prognosis of the patients [1-3]. Therefore, the pathogenesis of the IVC received much attention. Finding the pathogenesis for IVC could help because there were not satisfying treatment method [16,17].

IVC was considered as the sign of avascular osteonecrosis of the vertebral [18]. Dupuy et al [19] and Libicher et al [5] both revealed the avascular osteonecrosis of the vertebral in the IVC patients by the biopsies. Once vertebral compression fracture happened, the vertebra needed more blood supply in osteocyte growth and vertebral reconstruction[20]. If the artery could not provide sufficient blood supply, the osteogenesis might arrest and the vertebral nonunion happened.

The hypothesis of the vertebral ischemic theory was proposed. Nambu et al [21] showed that bilateral segmental artery ligation reduced the vertebral blood flow. Lin et al [9] used dynamic contrast-enhanced magnetic resonance imaging to assess the vertebral bone marrow perfusion of the adjacent vertebrae and found that the IVC formation was associated with the poor marrow perfusion. Kim et al [10] found that there was around 60% segmental artery occlusion in the IVC levels by MRA. All these indicated the occlusion of the segmental arteries might have an association with IVC. However, the lack of a control group made Kim's studies impossible to provide solid evidence for the relation of the arteries occlusion and IVC. Therefore, we performed this study to further elucidate the association between the formation of the IVC and segmental artery occlusion.

The LOSR and TOR had no significant difference between the IVC and non-IVC group. LOSR was considered as influencing the local vertebrae blood supply and the TOR reflected the whole vertebrae blood supply. The result indicated that vertebral segmental artery occlusion was not associated with the formation of the IVC. Once the segmental artery occlusion happened, the vertebral collateral arteries might form to compensate the vertebra blood supply [15] (Fig. 4). Therefore, the MRA detection for the artery occlusion may not absolutely reflect the vertebral ischemia condition. Segmental arteries occlusion could not be used for predicting the IVC formation.

From the T10 to the L4, there were pairs of segmental arteries of the vertebrae. The L5 segmental artery was the median sacral artery, which was not included in the assessment [22]. We assessed the artery condition from T10 to L4 and found that the vertebral arteries were more likely occluded in the thoracic-lumbar region. This region is a transition zone from the thoracic to the lumbar which has the maximum motion range and suffered much stress [18]. Both two factors lead the thoracic-lumbar region arteries prone to occlude. No relation was found between the vertebral fracture and the artery occlusion. The occlusion rate of the fracture levels is almost the same with the total segmental artery occlusion rate. This indicated that the vertebral fracture might not lead to the segmental artery occlusion, which was opposite to the view of Kim [10].

There were several limitations. This is not a large-scale study. However, we calculated the sample size according to previous studies and considered that the sample size was enough to draw a conclusion. The

detection of the IVC and artery occlusion was at the same time point. Hence, the influence of vertebral long-term ischemia could not be detected. Artery occlusion without IVC formation did not mean the IVC would not form after the MRA examination. A repeated MRI evaluation might help to further investigate.

Conclusions

Some previous studies provided clues for the relationship between segmental artery occlusion and IVC. However, we provided opposite evidence that the segmental artery occlusion did not lead to the IVC. And vertebral compression fracture was unrelated to the segmental artery occlusion. The segmental artery occlusion was more likely to happen in the thoracolumbar levels.

Declarations

Funding

This work was supported by the Beijing Municipal Science and Technology Project [grant number D161100002816001]; This work was supported by the Ministry of Education Key Laboratory of trauma treatment and nerve regeneration [grant number BMU2019XY007-01].

Authors' contributions

TYZ and FX conceived the study. TYZ performed data collection, designed method, and drafted manuscript. YK helped to performed the MRA for the patients. YHW helped to collect the data. PXZ and DYZ revised the manuscript. BGJ take responsibility for this study and apply the funding grants. All authors have read and approved the final manuscript.

Acknowledgments

Tianyu Zhang would like to thank Yue Liao for English language editing as well as silent support for life and work.

Authors details

The authors declare that they have no competing interests.

Ethics approval and consent to participate

The Ethics Review Committee of Peking University People's Hospital approved this study. The informed consent was acquired from the patients. The study protocol was performed in accordance with the relevant guidelines

Availability of data and materials

The data are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Code availability

Not applicable.

Competing interests

Tianyu Zhang, Feng Xue, Yu Kang, Yanhua Wang, Peixun Zhang, Dianyi Zhang, and Baoguo Jiang declare that they have no conflict of interest

References

1. Zhang TY, Zhang PX, Xue F, Zhang DY, Jiang BG (2020) Risk factors for cement leakage and nomogram for predicting the intradiscal cement leakage after the vertebra augmented surgery. BMC musculoskeletal disorders 21 (1):792. doi:10.1186/s12891-020-03810-4
2. Yu W, Liang, Yao Z, Qiu T, Ye L, Huang X, Jiang X (2017) Risk factors for recollapse of the augmented vertebrae after percutaneous vertebroplasty for osteoporotic vertebral fractures with intravertebral vacuum cleft. Medicine 96 (2):e5675
3. Zhang T, Wang Y, Zhang P, Xue F, Zhang D, Jiang B (2020) What Are the Risk Factors for Adjacent Vertebral Fracture After Vertebral Augmentation? A Meta-Analysis of Published Studies. Global spine journal:2192568220978223. doi:10.1177/2192568220978223
4. Huang YS, Hao DJ, Wang XD, Sun HH, Du JP, Yang JS, Gao J, Xue P (2018) Long-Segment or Bone Cement-Augmented Short-Segment Fixation for Kummell Disease with Neurologic Deficits? A Comparative Cohort Study. World neurosurgery 116:e1079-e1086. doi:10.1016/j.wneu.2018.05.171
5. Libicher M, Appelt A, I, Baier M, Meeder P, Grafe I, Dafonseca K, Noldge G, Kasperk C (2007) The intravertebral vacuum phenomen as specific sign of osteonecrosis in vertebral compression fractures: results from a radiological and histological study. European Radiology 17 (9):2248-2252
6. Armingeat T, Pham T, Legre V, Lafforgue P (2006) Coexistence of intravertebral vacuum and intradiscal vacuum. Joint bone spine 73 (4):428-432. doi:10.1016/j.jbspin.2005.10.011
7. He D, Yu W, Chen Z, Li L, Zhu K, Fan S (2016) Pathogenesis of the intravertebral vacuum of Kummell's disease. Experimental and therapeutic medicine 12 (2):879-882. doi:10.3892/etm.2016.3369
8. Kim HS, Kim SH, Ju CI, Kim SW, Lee SM, Shin H (2010) The role of bone cement augmentation in the treatment of chronic symptomatic osteoporotic compression fracture. Journal of Korean Neurosurgical Society 48 (6):490-495. doi:10.3340/jkns.2010.48.6.490
9. Lin WC, Chen HL, Lu CH, Wang HC, Wu RW, Cheng YF, Lui CC (2011) Dynamic contrast-enhanced magnetic resonance imaging for evaluating intraosseous cleft formation in patients with

osteoporotic vertebral compression fractures before vertebroplasty. Spine 36 (15):1244-1250. doi:10.1097/BRS.0b013e3181eb9b6c

10. Kim YC, Kim YH, Ha KY (2014) Pathomechanism of intravertebral clefts in osteoporotic compression fractures of the spine. The spine journal : official journal of the North American Spine Society 14 (4):659-666. doi:10.1016/j.spinee.2013.06.106
11. Kurunlahti M, Karppinen J, Haapea M, Niinimäki J, Autio R, Vanharanta H, Suramo I, Tervonen O (2004) Three-year follow-up of lumbar artery occlusion with magnetic resonance angiography in patients with sciatica: associations between occlusion and patient-reported symptoms. Spine (Phila Pa 1976) 29 (16):1804-1808; discussion 1809. doi:10.1097/01.brs.0000134576.77709.64
12. Shein-Chung Chow JS, Hansheng Wang, Yuliya Lokhnygina (2018) Sample Size Calculations in Clinical Research, vol 4.7. Third Edition. Taylor & Francis Group, Boca Raton
13. Formica M, Zanirato A, Cavagnaro L, Basso M, Felli L (2018) What is the Current Evidence on Vertebral Body Osteonecrosis?: A Systematic Review of the Literature. Asian spine journal 12 (3):586-599
14. Yu W, Liang, Yao Z, Qiu T, Ye L, Huang X, Jiang X (2017) Risk factors for recollapse of the augmented vertebrae after percutaneous vertebroplasty for osteoporotic vertebral fractures with intravertebral vacuum cleft. Medicine 96 (2):e5675. doi:10.1097/MD.0000000000005675
15. Kauppila LI (1997) Prevalence of stenotic changes in arteries supplying the lumbar spine. A postmortem angiographic study on 140 subjects. Ann Rheum Dis 56 (10):591-595. doi:10.1136/ard.56.10.591
16. Huang YS, Hao DJ, Feng H, Zhang HP, He SM, Ge CY, Niu XB (2018) Comparison of Percutaneous Kyphoplasty and Bone Cement-Augmented Short-Segment Pedicle Screw Fixation for Management of KÃ¼mmell Disease. Medical Science Monitor International Medical Journal of Experimental & Clinical Research 24:1072
17. Lu W, Wang L, Xie C, Teng Z, Han G, Shi R, Liang J, Lu S (2019) Analysis of percutaneous kyphoplasty or short-segmental fixation combined with vertebroplasty in the treatment of Kummell disease. Journal of orthopaedic surgery and research 14 (1):311. doi:10.1186/s13018-019-1358-8
18. Heo DH, Chin DK, Yoon YS, Kuh SU (2009) Recollapse of previous vertebral compression fracture after percutaneous vertebroplasty. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA 20 (3):473-480. doi:10.1007/s00198-008-0682-3
19. Dupuy DE, Palmer WE, Rosenthal DI (1996) Vertebral fluid collection associated with vertebral collapse. AJR American journal of roentgenology 167 (6):1535-1538. doi:10.2214/ajr.167.6.8956592
20. Braunstein V, Sprecher CM, Gisep A, Benneker L, Yen K, Schneider E, Heini P, Milz S (2008) Long-term reaction to bone cement in osteoporotic bone: new bone formation in vertebral bodies after vertebroplasty. Journal of anatomy 212 (5):697-701. doi:10.1111/j.1469-7580.2008.00883.x
21. Nambu K, Kawahara N, Kobayashi T, Murakami H, Ueda Y, Tomita K (2004) Interruption of the bilateral segmental arteries at several levels: influence on vertebral blood flow. Spine (Phila Pa 1976)

29 (14):1530-1534. doi:10.1097/01.brs.0000131420.32770.06

22. Tezuka F, Sakai T, Nishisho T, Takata Y, Higashino K, Takao S, Harada M, Sairyo K (2016) Variations in arterial supply to the lower lumbar spine. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society 25 (12):4181-4187. doi:10.1007/s00586-016-4427-2

Tables

Table 1 Characteristics of Patients

Variable	Total (n=44)
Age (years)	74.6 (12.38)
Sex (female)	30 (68.2)
BMI (kg/m^2)	23.19 (3.04)
Severity of fracture (>25% collapse)	20 (44.4%)
CR (%)	79 (18%)
time from injury to MRI (Days)	21 (44.5)
Thoracolumbar levels	34 (77.3)
Mean-LSOR (%)	15.2
Mean-TOR (%)	15.3

Table 2 Comparison of the non-IVC group with IVC group.

Factors	IVC (n=21)	Non-IVC (n=25)	P values
Age (years)	76.48 (12.46)	72.64 (12.14)	0.297
Gender (female)	15 (71.4%)	17 (68.0%)	0.801
BMI (kg/m^2)	22.72 (3.10)	22.34 (2.94)	0.486
Vertebral avascular risk factors	24.69	22.50	0.563
Thoracolumbar levels (yes)	17 (81.0%)	17 (68.0%)	0.319
Fracture severity (>25%)	10 (47.6%)	9 (36%)	0.425
CR (%)	77.94 (20.26)	81.11 (16.83)	0.861
Time from injury to MRI (Days)	39.69 (64.49)	9.07(12.18)	0.041*
LSOR (%)	20.24 (28.1)	11.11 (20.5)	0.205
TOR (%)	13.83 (12.0)	11.57 (9.2)	0.476

*P<0.05. LSOR = lesion segmental occlusion rate, TOR = total occlusion ratio

Figures

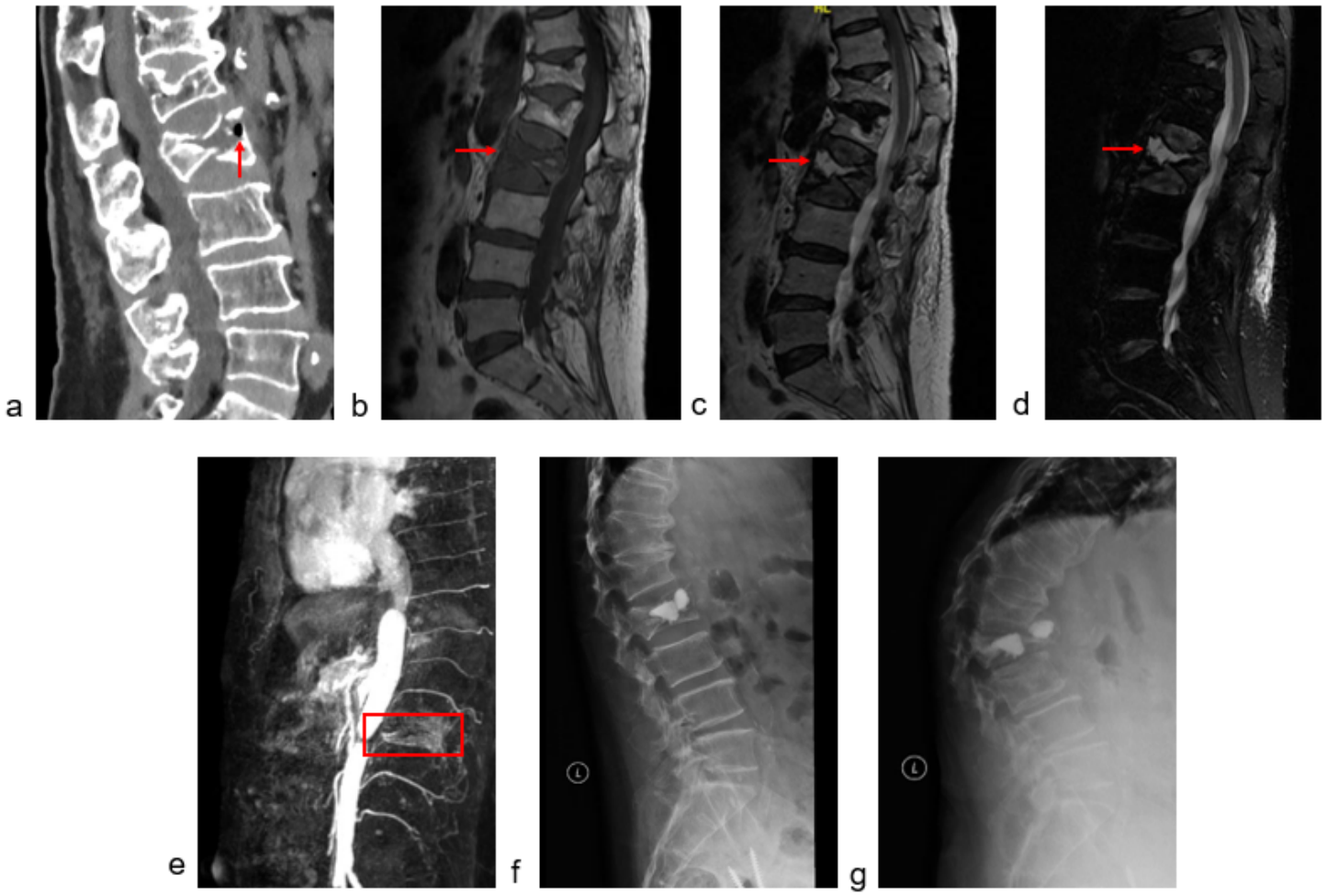

Figure 1

An eighty-two-year-old female suffered from severe back pain for about 17 days (VAS 9) after the left object. The CT showed the L2 compression fracture with intravertebral cleft formation (a) and MRI indicated an area of hypointensity on T1-weighted and hyperintensity on T2-weighted and T2-fat suppression images (b,c,d, red arrow). MRA revealed that both sides of the L2 arteries were occluded (e). Unilateral vertebroplasty was performed for the patients (f). The augmented vertebra recollapse with the cement displacement (g) happened after a half year of the procedure.

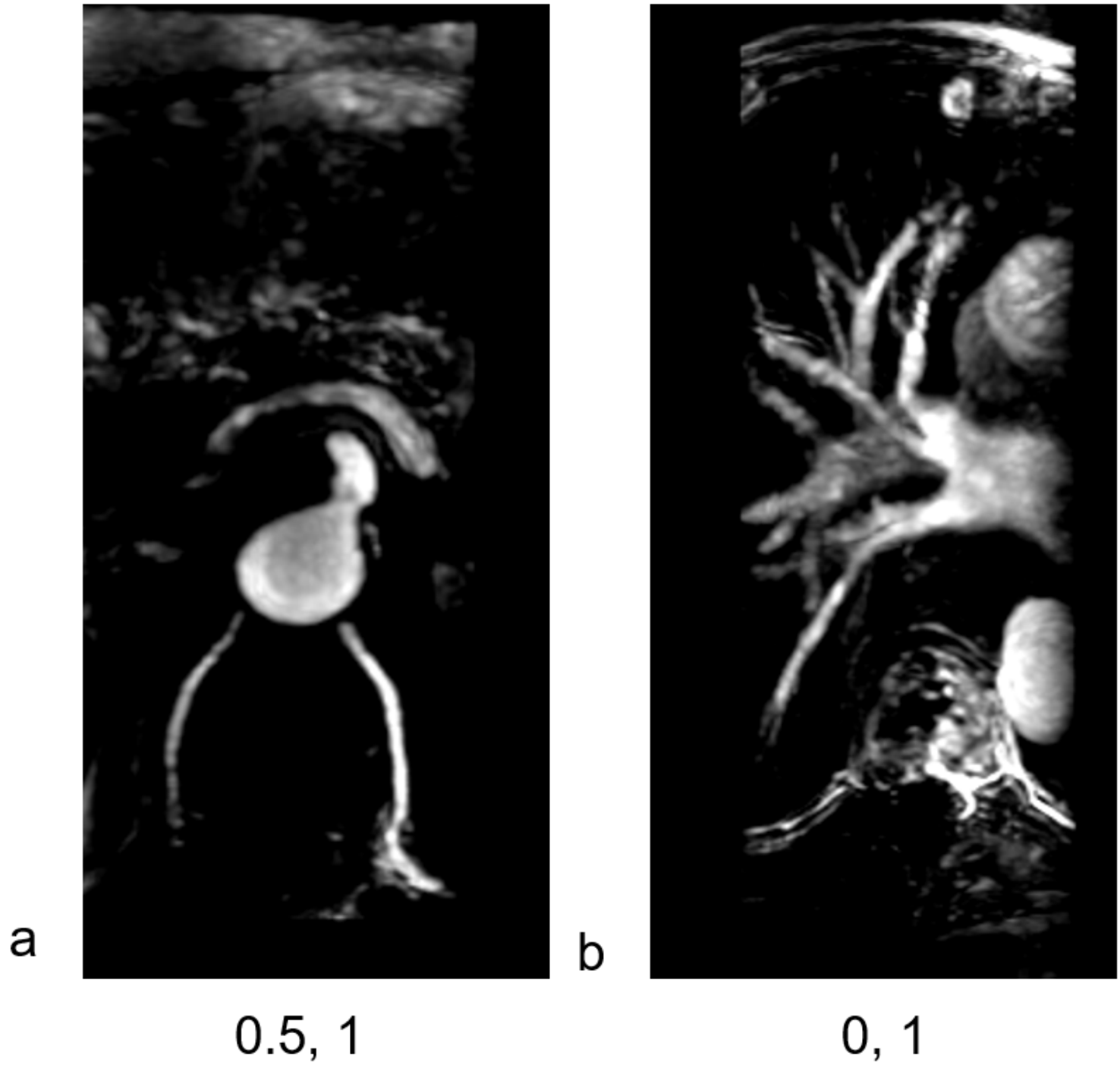

Figure 2

Each vertebral artery condition was classified into patency, narrow, occlusion and was scored in 1, 0.5, 0.

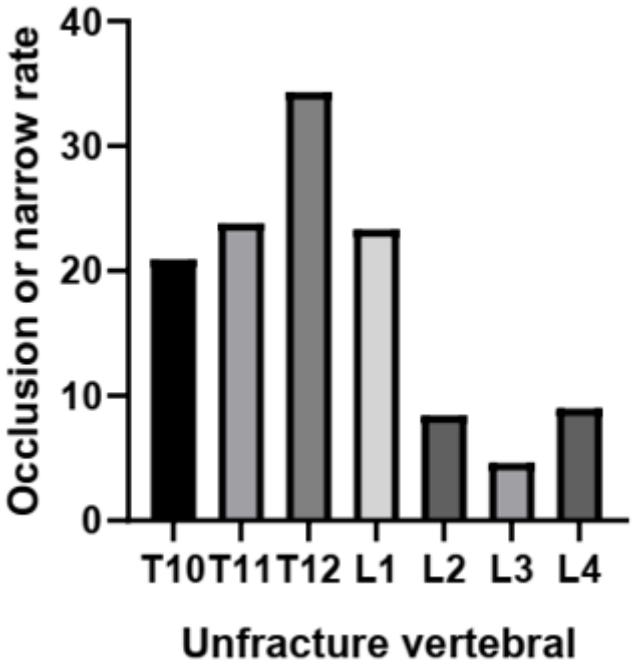

Figure 3

The occlusion and narrow rate of each unfractured vertebral artery.

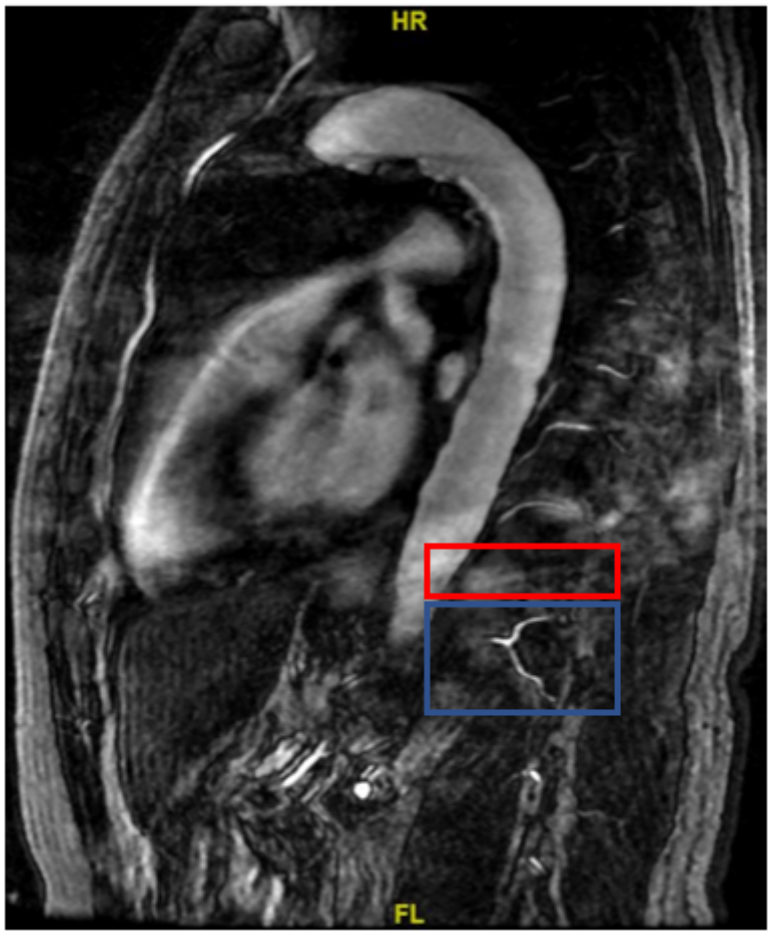

Figure 4

Adjacent level vertebral artery formed collateral artery (blue) to the occlusion level (red).