Symptomatic Residual Bone Fragment of the Superior Articular Process After Percutaneous Transforaminal Endoscopic Discectomy

Jihui Zhang
Ningbo No.6 Hospital
Liujun Zhao (zhaoliujun555@sina.com)
Ningbo No.6 Hospital
Baoshan Xu
Tianjin Hospital Spine Surgery
Gang Chen
The Second Affiliated Hospital of Zhejiang University, of Medical
Feng Qi
Ningbo Li Huili Hospital
Wenfei Ni
The Second Affiliated Hospital of Wenzhou Medical University
Huimin Zhu
Armed Police Coprs Hospital of Henan
Yongjie Gu
Ningbo No.6 Hospital
Liang Yu
Ningbo No.6 Hospital
Fangcai Li
The Second Affiliated Hospital of Zhejiang University, of Medical

Research Article

Keywords: complication, foraminoplasty, percutaneous transforaminal endoscopic discectomy, residual bone fragment, superior articular process, symptomatic

Posted Date: September 22nd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-893070/v1

Abstract

Purpose: To demonstrate the clinical characteristics of symptomatic residual bone fragment of the superior articular process (symptomatic-RBF-SAP) after percutaneous transforaminal endoscopic discectomy (PTED), and to discuss its types and revision strategies.

Methods: We retrospectively analyzed 556 consecutive patients who underwent PTED between July 2015 and November 2017; seven (1.2%) of whom experienced symptomatic RBF-SAP. Clinical outcomes were evaluated using the visual analog scale (VAS), Oswestry disability index (ODI), and modified MacNab criteria.

Results: Intractable radicular leg pain was the most common symptom. Symptoms occurred late in 2 patients (>3 days) and early (<3 days) in five patients. Symptoms occurred on the contralateral side in two early cases. Cerebrospinal fluid (CSF) leakage and nerve injury were secondary complications in one early case. CSF leakage also occurred in one delayed case. Patients with radicular leg pain underwent secondary repair surgery. The mean follow-up period was 17.7 months, VAS of radicular leg pain improved from 8.7 to 1.8, and ODI improved from 74.5% to 23.9%. The final outcomes were excellent, good, and fair in one, three, and two patients, respectively.

Conclusions: Foraminoplasty for PTED may increase the risk of symptomatic-RBF-SAP. If this occurs, revision surgery is required, not only for severe pain, but also for secondary complications that may occur.

Introduction

Percutaneous transforaminal endoscopic discectomy (PTED) is widely used to treat lumbar degeneration, particularly cases of lumbar disc herniation and lumbar spinal stenosis. This procedure, which is performed under local anesthesia, has many advantages, such as less preoperative anxiety, minimized risk compared to techniques that require general anesthesia, and reduced instability[1–5]. Additionally, PTED is less traumatic (only a 7—8-mm incision is required), has a shorter duration of inpatient time, and causes less paravertebral muscle injury[6–9].

Incidental residual bone fragment after spine surgery are one of the most important complications in many clinical studies. New neurological deficits caused by residual bone fragment have been reported after osteotomy operations, and clinical manifestations include pain, numbness, and muscle weakness. The clinical features and treatment of these deficits have also been described. Therefore, defining this complication is important for patient counseling, quality improvement, and potential medicolegal issues[10].

Theoretically, the risk of residual bone fragment and subsequent new neurological deficit, termed symptomatic residual bone fragment of the superior articular process (symptomatic-RBF-SAP), may be relatively low, although not non-existent, in patients who undergo PTED. Compared to surgery for severe spinal deformities, osteotomy is not performed in PTED. Choi et al.[11] reported that the use of a bone

reamer to undercut the articular process is essentially a blind procedure, even when it is performed under fluoroscopic guidance, as there is no control over the amount of bone removed and bleeding from the bone. The incidence and clinical effects of symptomatic-RBF-SAP associated with PTED are unknown. Therefore, we sought to evaluate the clinical characteristics of symptomatic-RBF-SAP after PTED and to discuss the different types and revision strategies for this underestimated complication.

Materials And Methods

Data collection

The retrospective study was approved by the Ethical Committee of Ningbo No.6 Hospital, the Ethical Committee of Tianjin Hospital, the Ethical Committee of The Second Affiliated Hospital of Zhejiang University, the Ethical Committee of Ningbo Li Huili Hospital, the Ethical Committee of The Second Affiliated Hospital of Wenzhou Medical University and the Ethical Committee of Armed Police Coprs Hospital of Henan. The study was carried out in accordance with the relevant guidelines and regulations, and informed consent was obtained from all participants. We reviewed our database for patients who had undergone PTED at six hospitals between July 2015 and November 2017. A total of 556 consecutive cases were treated with PTED by six surgeons. The inclusion criteria were as follows: (1) lumbar disc herniation, lumbar spinal stenosis, and soft lumbar disc herniation demonstrated on preoperative magnetic resonance imaging (MRI) and computed tomography (CT) scans; (2) failure of conservative treatment after more than 6 months; and (3) no previous lumbar surgery at the same disc level. The exclusion criteria were (1) the presence of cardiovascular diseases, spinal tumor, fracture, or infection; and (2) spinal instability, narrowed foramen, lateral recess stenosis, or calcified disc herniation.

The patients' medical records were retrospectively examined. Among the 556 consecutive PTED cases in the database, seven cases of PTED-associated symptomatic-RBF-SAP were found. Residual bone fragment were confirmed using CT or secondary open surgery. Clinical outcomes were evaluated using a visual analog scale (VAS) for pain intensity and the Oswestry Disability Index (ODI) to assess functional status[12]. The patients' clinical outcomes were also classified as excellent, good, fair, or poor based on the modified MacNab criteria[13].

Surgical procedure

PTED was performed in the prone position, as previously described[5, 8]. The surgeon operated while standing on the symptomatic side and positioned the video monitor on the opposite side. The skin entry point was typically lateral, 8—14 cm from the midline. An 18-gauge spinal needle was introduced after the entry point was infiltrated with local anesthetics under the guidance of C-arm fluoroscopy. The final target point was then infiltrated with 2—3 cc of 1% lidocaine in the medial pedicular line on the anteroposterior image and the posterior vertebral line on the lateral image. When the spinal needle punctured the targeted disc, contrast medium mixed with indigo carmine dye was introduced to stain the pathological nucleus, in order to make locating the annular tear easier. The following steps were then performed. First, we made

an 8-mm skin incision, and the spinal needle was replaced with a guidewire. The working channel was then introduced over the guide wire, successively from thin to wide dilators, until the tip of the working cannula was located on the herniated disc, close to the posterior longitudinal ligament. Next, foraminoplasty was performed, and the SAP was undercut using a bone reamer or bone cutter[14, 15]. Next, an endoscope (Wolf, Tuttlingen, Germany) was inserted through the working cannula, and an irrigation system was connected. The pathological nucleus was easily distinguished due to the stain used, and the herniated disc fragment was then removed using forceps and a laser once the posterior longitudinal ligament was loosened and a favorable pulse of the dura sac was observed. Finally, the skin was closed using sutures.

Statistical analysis

The data were statistically processed by SPSS 17.0 statistical software (SPSS Inc, Chicago, Illinois, USA), and the measurement data were expressed as mean ± SD.

Results

Demographics and types of symptomatic residual bone fragment of the superior articular process

A total of 556 patients with radicular leg pain underwent PTED between July 2015 and November 2017. The study population included 379 female and 177 male patients with an average age of 46.7 (range, 32–85) years. Seven patients (1.2%) experienced symptomatic-RBF-SAP associated with PTED. These included six female and one male patient, with a mean age of 67.3 (range, 57—83 years). All female patients had attained menopause. The operative segments were L2/3 in one, L3/4 in two patients, L4/5 in three, and L5/S1 in one patient. No bone fragment was observed intraoperatively. Symptoms only appeared after PTED, within an average of 7.5 hours (range, 6——10 hours) in five patients (early type), all of whom complained of radicular pain (four cases with leg pain and one with low back pain), and after a symptom-free interval in two patients (delayed type). Symptoms were found to be caused by a residual bone fragment rather than by recurrent disc herniation or a hematoma, based on a postoperative CT scan or secondary open surgery. The leg pain was severe, aggravated by activity, and unresponsive to conservative management. Patients with low back pain did not experience serious pain, and conservative treatment was effective.

Based on the location of the residual bone fragment, the seven cases were classified into two categories: (1) ipsilateral residue, with the residual bone fragment on the same side as the initial symptom (n=2 early type) (Fig.1), and (2) contralateral residue, with the bone fragment on the contralateral side (n=3 early type, 2 delayed type) (Fig.2). The location of the residual bone fragment was easily detected on CT, but in one patient, neither CT nor MRI revealed the bone fragment; it was only found during the secondary operation. Fig.1

One patient refused secondary surgery due to fear. Other patients underwent secondary surgery using different approaches. The shortest revision time was 2 days, and the longest was 3 months. The strategy for revision was microendoscopic discectomy in two cases and mobile microendoscopic discectomy, small incision operation, PTED, and minimally invasive transforaminal lumbar interbody fusion (Mis-TLIF) in one patient each, and these procedures succeeded in removing the residual bone fragment in all cases. The largest bone fragment was 8 mm × 8 mm × 2 mm, and the smallest was 6 mm × 3 mm × 2 mm. The contralateral residual bone fragment was larger than the ipsilateral fragment.

One delayed case had a secondary complication of CSF leakage, and a small piece of gelatin sponge was used to seal the defect in the dura. However, one early type patient had both CSF leakage and nerve root injury. After treatment, motor function improved from grade 3/5 to 4/5.

Clinical outcomes

Over the mean follow-up period of 17.7 months (range, 16–23 months), the mean VAS of radicular leg pain decreased from 8.7 (SD 0.8) to 1.8 (SD 0.8), and mean ODI improved from 74.5% (SD 4.5%) to 23.9% (SD 6.8%). Based on the modified MacNab criteria, the final outcome was excellent in one patient, good in three patients, and fair in two patients. Patients with low back pain who refused revision surgery had a post-PTED VAS score of 4 and an ODI of 17/50 (34%), and a VAS score of 3 and ODI of 15/50 (30%) at the last follow-up.

Discussion

We described the clinical characteristics of early and delayed symptomatic-RBF-SAP post-PTED and showed that intractable radicular leg pain was the most common symptom and was caused by ipsilateral or contralateral residual bone fragment, which could be removed through revision surgery.

Foraminoplasty in PTED

All patients with symptomatic RBF-SAP underwent foraminoplasty during PTED. Foraminoplasty involves widening the foramen by undercutting the ventral part of the SAP, with ablation of the foraminal ligament, using bone trephines or an endoscopic drill and side-firing lasers, to visualize the anterior epidural space and its contents[11]. Foraminoplasty was performed to avoid damaging the exiting nerve during endoscopic cannula insertion into the neural canal through the intervertebral foramen. Henmi et al. evaluated the intervertebral foramen pre- and postoperatively using CT and found that the mean foraminal area increased significantly from 58.6 to 88.4 mm^2[16]. However, bone destruction increases the possibility of residual bone fragment. Foraminoplasty is performed blindly and depends greatly on the surgeon's experience. Some bone fragment may not be removed after the SAP is cut. When the site of foraminoplasty is not ideal, adjusting the direction of the working cannula is often necessary to improve decompression. In elderly patients, care should be taken to reduce the risk of residual bone fragment due to osteoporosis. Foraminoplasty demands on the surgeon's technical skill and experience, and remains challenging even for skilled surgeons[17].

Types of residual bone fragment according to time, location, and shape

In the delayed cases, symptoms appeared following a period of improvement after they had been discharge. Two of the seven patients complained of radicular leg pain 1 week after discharge and another complained 1 month after being discharged. A residual bone fragment was diagnosed using CT in both patients. The reason for delayed symptoms may be that the location of the bone fragment changed with activity, and symptoms appeared when the dural sac or exiting nerve root was compressed by the displaced bone fragment. Irrespective of whether conservative treatment is effective, surgical removal of bone fragment is recommended. The bone fragment is completely separated from the ligament; therefore, it can move anywhere in the spinal canal during conservative treatment, and symptoms may appear gradually, even on the opposite side. Moreover, it can cause injury to the nerve root and dural sac.

In contrast, in early cases, symptoms appeared soon after the surgery. Within hours after PTED, patients could not sit or walk because of intractable radicular pain, which was similar to mechanical compression of the nerve root and dural sac. In osteotomy surgery, neurological deficits can be caused by inadvertent placement of implants or compromise of the blood supply to the cord. However, no implant was used, and the dura did not move during PTED. It is difficult for surgeons to determine whether symptoms are caused by residual bone fragment. In all seven cases, the rare complication was recognized using CT or secondary intraoperative exploration; no fragment was found during the initial surgery. In PTED, patients are awake and under local anesthesia and can provide instant feedback to surgeons[18]. One of our patients complained of leg pain when the surgeon adjusted the working cannula intraoperatively, but the surgeon considered this to be a normal phenomenon during surgery. In such cases, a bone fragment may be found by exploration, which can prevent rare complications and secondary surgery. Alternatively, a CT scan can be performed during surgery (if conditions permit). For open surgery, residual bone fragment can reportedly cause neurological deficits, including nerve root, cauda equina, and spinal cord deficits. In our study, the incidence of symptomatic-RBF-SAP was 1.2%; however, although the rate was low, its effect on patients cannot be ignored. Additionally, asymptomatic RBF-SAP was encountered, but the rate was low. In our study, only nerve root deficit occurred, possibly due to the anatomy of the intervertebral foramen and exiting nerve root. The residual bone fragment of the SAP after foraminoplasty becomes a foreign body in the foramen that can be pushed into the spinal canal by inserting a working cannula after foraminoplasty. Due to the limited space in the spinal canal, symptoms of nerve root deficit can easily occur.

In the early cases, two patients experienced pain on the contralateral side. Typically, people will consider recurrence at the same location or other levels first, which may be due to activity or an undiscovered herniated intervertebral disc. In one of our patients, a mixed signal in the spinal canal was detected using MRI (Fig. 3), although CT was not performed after the operation, MRI found only a hematoma. Although epidural hematoma is the most common cause of postoperative neurological deficits [19], a residual bone

fragment was found during revision surgery in this patient. The bone fragment may have resulted from foraminoplasty and could have been pushed to the opposite side and moved across the midline during cannula placement. Interestingly, no contralateral cases occurred in the delayed type. Contralateral bone fragment move from side to side over time; thus, ipsilateral cases are expected to occur early.

The two largest bone fragment were in contralateral cases. These may have been easily pushed to the opposite side while manipulating the cannula, as small bone fragment may have been pushed around the working cannula. Jacob et al. noted that neurological deficits were always unilateral, were never proximal to, and usually did not correspond to the level of the osteotomy. This was thought to be due to a combination of subluxation, residual dorsal impingement, and dural buckling[20]. Although the residual bone fragment was also unilateral in PTED, the deficit was at the same level. None of the patients had more than one residual bone fragment.

Residual bone fragment may also cause secondary complications unrelated to early or delayed types. Although there have been no reports of secondary complications in open surgery, this complication is related to the shape of the bone fragment. The sharp edge of the fragment can injure nerve roots and the dural sac. If the dural sac is punctured, CSF leakage occurs, and this increases the risk of infection. It may also cause neural entrapment syndrome when the nerve root is compressed by a dural tear. Two patients (28.6%) had CSF leakage, and one patient (14.3%) had nerve injury. Secondary complications are associated with the risk of recurrence if the fragment is not removed.

Revision strategy of residual bone fragment

Some studies have reported new neurological deficits caused by residual bone fragment after open spinal surgery[10, 19–21]. Some patients in these studies responded to conservative treatment, while others required revision surgery. With laminectomy, the spinal canal volume increases, and the probability of successful conservative treatment is increased. However, our PTED patients did not have changes in spinal canal stenosis; thus, conservative treatment was less useful. One patient with low back pain refused surgery because of fear, while the others underwent various types of revision surgery. The VAS score decreased in all patients, irrespective of the revision surgery type.

Conclusions

Although PTED is a minimally invasive and relatively safe procedure, surgeons should consider the complications of symptomatic-RBF-SAP, particularly when foraminoplasty is performed. Symptomatic-RBF-SAP always requires revision, not only due to severe pain, but also due to the risks of secondary complications.

Declarations

Funding: No funding was received to assist with the preparation of this manuscript.

Competing interests: The authors declare no competing interests

Author contributions: JH.Z., and LJ.Z. conceived and designed the study. BS.X., G.C., and F.Q. collected the data. WF.N., HM.Z., and YJ.G. analyzed the data. L.Y., and FC.L. performed statistical analyses. JH.Z., and LJ.Z. drafed the manuscript. All authors reviewed and revised the manuscript.

Additional information: Correspondence and requests for materials should be addressed to JH.Z. or LJ.Z.

References

1. Sinkemani, A. *et al.* Outcomes of microendoscopic discectomy and percutaneous transforaminal endoscopic discectomy for the treatment of lumbar disc herniation: A comparative retrospective study. *Asian Spine J*, **9**, 833–840 https://doi.org/10.4184/asj.2015.9.6.833 (2015).
2. Choi, K. C. *et al.* Percutaneous endoscopic lumbar discectomy for L5-S1 disc herniation: transforaminal veRBF-SAPus interlaminar approach. *Pain Phys*, **16**, 547–556 https://doi.org/10.1097/brs.0000000000002901 (2013).
3. Li, X. H. *et al.* Percutaneous endoscopic lumbar discectomy for recurrent lumbar disc herniation. Int. J. Surg. 27, 8–16(2016). 10.1016/j.ijsu.2016.01.034, Pubmed:26805569.
4. Han, G., Yang, W. F., Zhang, S. & Jiang, F. Analysis and treatment of surgical complications after percutaneous transforaminal endoscopic discectomy for treating lumbar disc herniation and lumbar intervertebral foraminal stenosis. *Chin. J. Contemp. Neurol. Neurosurg*, **16**, 210–215 https://doi.org/10.5005/jp/books/12000_22 (2016).
5. Ahn, Y. Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications. Expert Rev. Med. Devices 9, 361–366(2012). 10.1586/erd.12.23, Pubmed:22905840.
6. Gadjradj, P. S., van Tulder, M. W., Dirven, C. M., Peul, W. C. & Harhangi, B. S. Clinical outcomes after percutaneous transforaminal endoscopic discectomy for lumbar disc herniation: a prospective case series. Neurosurg. Focus 40, E3(2016). 10.3171/2015.10.FOCUS15484, Pubmed:26828884.
7. Gu, Y. T., Cui, Z., Shao, H. W., Ye, Y. & Gu, A. Q. Percutaneous transforaminal endoscopic surgery (PTES) for symptomatic lumbar disc herniation: a surgical technique, outcome, and complications in 209 consecutive cases. J. Orthop. Surg. Res. 12, 25(2017). 10.1186/s13018-017-0524-0, Pubmed:28178992.
8. Yeung, A. T. & Tsou, P. M. Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. *Spine (Phila Pa 1976)*, **27**, 722–731 https://doi.org/10.1097/00007632-200204010-00009 (2002).
9. Choi, K. C. *et al.* Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10,228 cases. Neurosurgery 76, 372 – 80; discussion 380(2015). 10.1227/NEU.0000000000000628, Pubmed:25599214.
10. Hamilton, D. K. *et al.* Rates of new neurological deficit associated with spine surgery based on 108,419 procedures: a report of the scoliosis research society morbidity and mortality committee.

Spine, **36**, 1218–1228 https://doi.org/10.1097/BRS.0b013e3181ec5fd9 (2011).

11. Choi, G. *et al.* Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working channel endoscope. *Spine*, **33**, E508–E515 https://doi.org/10.1097/BRS.0b013e31817bfa1a (2008).
12. Pfirrmann, C. W., Metzdorf, A., Zanetti, M., Hodler, J. & Boos, N. Magnetic resonance classification of lumbar intervertebral disc degeneration. *Spine (Phila Pa 1976)*, **26**, 1873–1878 https://doi.org/10.1097/00007632-200109010-00011 (2001).
13. Macnab, I. Negative disc exploration: an analysis of the causes of nerve-root involvement in sixty-eight patients. *J. Bone Joint Surg. Am*, **53**, 891–903 https://doi.org/10.2106/00004623-197153050-00004 (1971).
14. Ahn, Y., Lee, S. H., Park, W. M. & Lee, H. Y. Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note. J. Neurosurg. 99 Supplement, 320–323(2003). 10.3171/spi.2003.99.3.0320, Pubmed:14563153.
15. Lee, S. H. *et al.* Foraminoplastic ventral epidural approach for removal of extruded herniated fragment at the L5-S1 level. *Neurol. Med. Chir (Tokyo)*, **50**, 1074–1078 https://doi.org/10.2176/nmc.50.1074 (2010).
16. Henmi, T., Terai, T., Nagamachi, A. & Sairyo, K. Morphometric changes of the lumbar intervertebral foramen after percutaneous endoscopic foraminoplasty under local anesthesia. J. Neurol. Surg. A Cent. Eur. Neurosurg. 79, 19–24(2018). 10.1055/s-0037-1599059, Pubmed:28320029.
17. Wang, H. *et al.* Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon's training level of minimally invasive spine surgery. *Clin. Neurol. Neurosurg*, **115**, 1987–1991 https://doi.org/10.1016/j.clineuro.2013.06.008 (2013).
18. Li, Z. Z., Hou, S. X., Shang, W. L., Song, K. R. & Zhao, H. L. Modified percutaneous lumbar foraminoplasty and percutaneous endoscopic lumbar discectomy: instrument design, technique notes, and 5 years follow-up. *Pain Phys*, **20**, E85–E98 https://doi.org/10.36076/ppj.2017.1.e85 (2017).
19. Rajasekaran, S., Subramani, S. & Shetty, A. P. Neurological deficit after spinal osteotomy. *Spinal Osteotomy*, 253–260 https://doi.org/10.1007/978-94-017-8038-4_19 (2015).
20. Buchowski, J. M. *et al.* Neurologic complications of lumbar pedicle subtraction osteotomy: a 10-year assessment. *Spine*, **32**, 2245–2252 https://doi.org/10.1097/BRS.0b013e31814b2d52 (2007).
21. Rustagi, T., Tallarico, R. A. & Lavelle, W. F. Early lumbar nerve root deficit after three column osteotomy for fixed sagittal plane deformities in adults. *Int. J. Spine Surg*, **12**, 131–138 (2018). 10.14444/5020, Pubmed:30276072.

Tables

Table 1
Information of seven cases after PTED

No	Age (year)	Sex	Segment	Never and dural sac	Size (mm)	Location	Time of reoperation	Method
1	60	Female	L4/5	/	6×3×2	Ipsilateral	/	/
2	63	Female	L5/S1	/	7×3×2	Ipsilateral	3 months	PTED
3	83	Female	L3/4	/	6×6×3	Ipsilateral	8 days	MED
4	78	Female	L2/3	CFL	8×5×3	Ipsilateral	14 days	MED
5	67	Female	L3/4	Nerve injury; CFL	6×5×4	Ipsilateral	2 days	MMED
6	63	Male	L4/5	/	8×8×2	Contralateral	7 days	small incision
7	57	Female	L4/5	/	8×4×3	Contralateral	2 days	Mis-TLIF

MED = Microendoscopic Discectomy, MMED = mobile Microendoscopic Discectomy, PTED = percutaneous trasforaminal endoscopic discectomy, Mis-TLIF = minimally invasive surgery transforaminal lumbar interbody fusion, CFL = cerebrospinal fluid leakage

Table 2
Clinical outcomes of revision for symptomatic-RBF-SAP associated with PTED

Case No.	VAS-leg		Oswestry disability index		McNab criteria	Follow-up (months)
	Preop	Postop	Preop	Postop		
1	-	-	-	-	-	18
E	8	1	35/45 (78%)	10/45 (22%)	Good	16
E	10	1	38/50 (76%)	8/50 (16%)	Excellent	19
4	9	2	36/45 (80%)	12/50 (24%)	Good	23
5	8	1	37/50 (74%)	9/50 (18%)	Good	21
6	9	3	34/50 (68%)	15/50 (30%)	Fair	10
7	8	2	31/45 (71%)	15/45 (33%)	Fair	17

symptomatic-RBF-SAP = symptomatic residual bone fragment of the superior articular process, PTED = percutaneous trasforaminal endoscopic discectomy

Figures

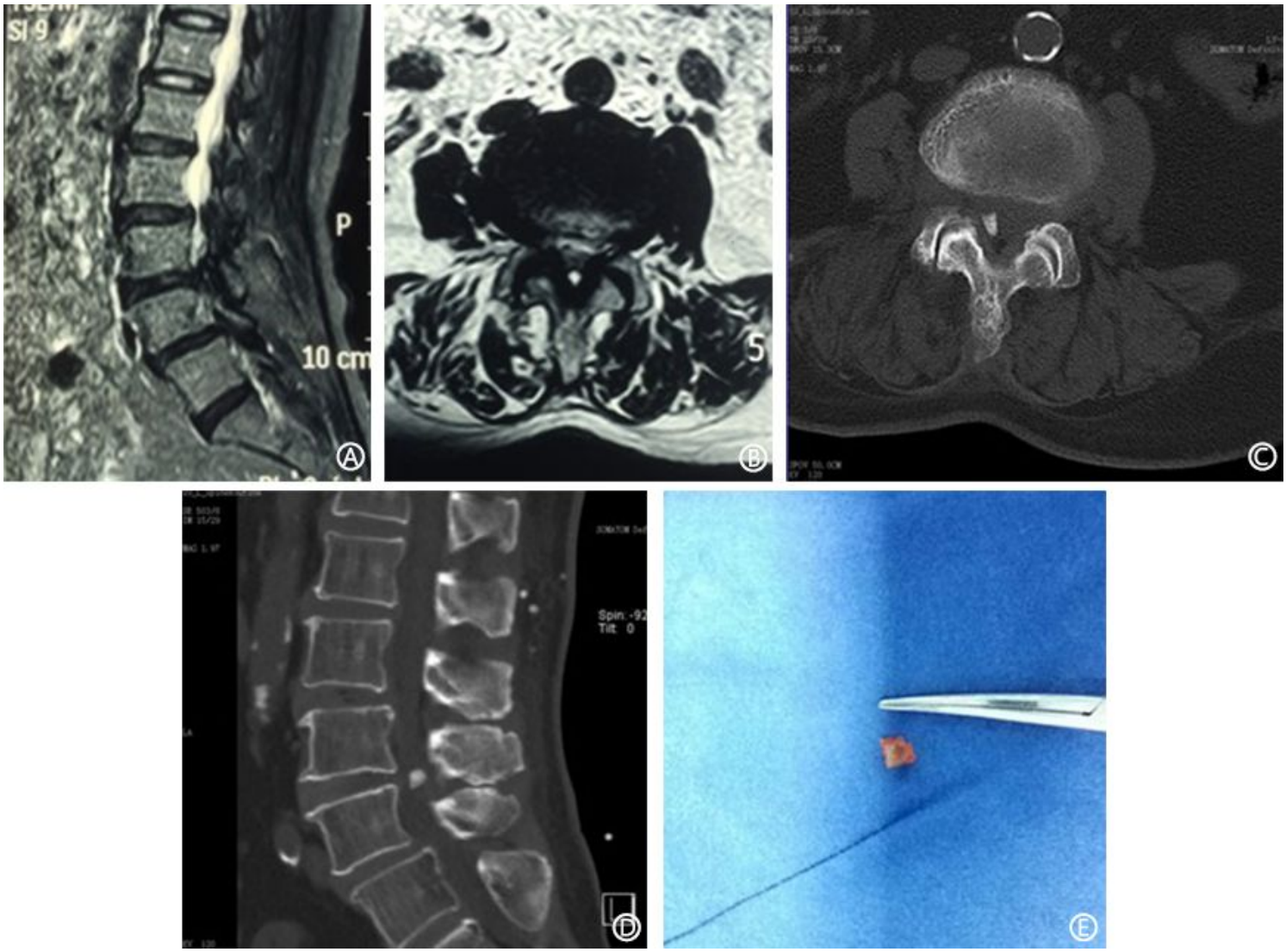

Figure 1

Illustrative case of symptomatic residual bone fragment of the superior articular process (symptomatic-RBF-SAP) on the ipsilateral side (case no. 3). An 83-year-old female patient underwent percutaneous transforaminal endoscopic discectomy (PTED) for a right-sided disc herniation at the L3/4 level (a, b). A residual bone fragment was detected postoperatively, using computed tomography, on the same side as the original symptoms (c, d). After revision, the residual bone fragment was removed (e)

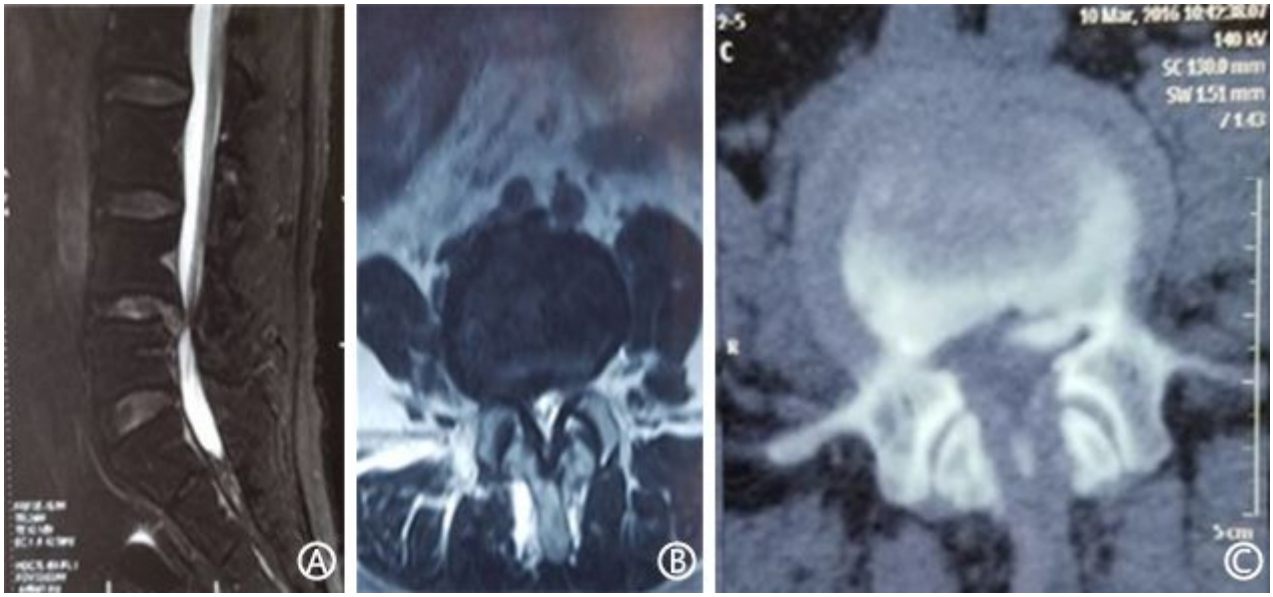

Figure 2

Illustrative case of symptomatic residual bone fragment of the superior articular process (symptomatic-RBF-SAP) in contralateral side (case no. 7). A 57-year-old female patient underwent percutaneous transforaminal endoscopic discectomy (PTED) for a right-sided disc herniation at the L4/5 level (a, b). A residual bone fragment was detected postoperatively, using computed tomography, on the contralateral side of the original symptoms (c)

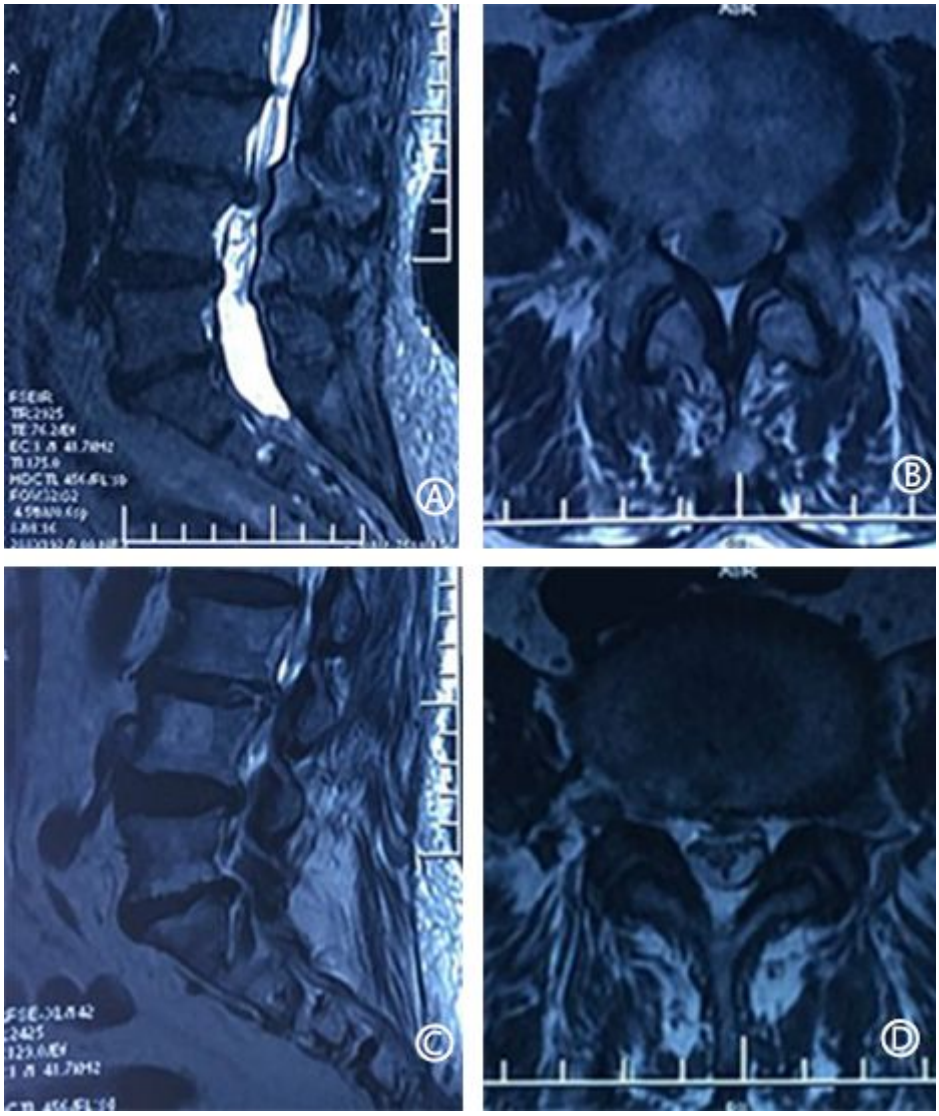

Figure 3

Illustrative case where magnetic resonance imaging (MRI) could not show the residual bone fragment (case no. 5). A 57-year-old female patient underwent percutaneous transforaminal endoscopic discectomy (PTED) for lumbar spinal stenosis at the L3/4 level (a, b). Postoperative MRI showed a mixed signal in the spinal canal, but did not reveal the residual bone fragment (c, d)