

World Journal of *Clinical Cases*

World J Clin Cases 2020 December 6; 8(23): 5835-6212



Contents

Semimonthly Volume 8 Number 23 December 6, 2020

EDITORIAL

- 5835** Understanding the immunopathogenesis of COVID-19: Its implication for therapeutic strategy
Shimizu Y

OPINION REVIEW

- 5844** What is the gut feeling telling us about physical activity in colorectal carcinogenesis?
Cigrovski Berkovic M, Cigrovski V, Bilic-Curcic I, Mrzljak A

REVIEW

- 5852** Latest developments in chronic intestinal pseudo-obstruction
Zhu CZ, Zhao HW, Lin HW, Wang F, Li YX

ORIGINAL ARTICLE

Case Control Study

- 5866** Correlation between ductus venosus spectrum and right ventricular diastolic function in isolated single-umbilical-artery foetus and normal foetus in third trimester
Li TG, Nie F, Xu XY

Retrospective Cohort Study

- 5876** Clinical efficacy of integral theory-guided laparoscopic integral pelvic floor/ligament repair in the treatment of internal rectal prolapse in females
Yang Y, Cao YL, Zhang YY, Shi SS, Yang WW, Zhao N, Lyu BB, Zhang WL, Wei D

Retrospective Study

- 5887** Treatment of Kümmell's disease with sequential infusion of bone cement: A retrospective study
Zhang X, Li YC, Liu HP, Zhou B, Yang HL
- 5894** Application value analysis of magnetic resonance imaging and computed tomography in the diagnosis of intracranial infection after craniocerebral surgery
Gu L, Yang XL, Yin HK, Lu ZH, Geng CJ
- 5902** Focal intrahepatic strictures: A proposal classification based on diagnosis-treatment experience and systemic review
Zhou D, Zhang B, Zhang XY, Guan WB, Wang JD, Ma F
- 5918** Preliminary analysis of the effect of vagus nerve stimulation in the treatment of children with intractable epilepsy
Fang T, Xie ZH, Liu TH, Deng J, Chen S, Chen F, Zheng LL

- 5926** Scoring system for poor limb perfusion after limb fracture in children
Zhu T, Shi Y, Yu Q, Zhao YJ, Dai W, Chen Y, Zhang SS
- 5935** Overexpression of CD155 is associated with PD-1 and PD-L1 expression on immune cells, rather than tumor cells in the breast cancer microenvironment
Wang RB, Li YC, Zhou Q, Lv SZ, Yuan KY, Wu JP, Zhao YJ, Song QK, Zhu B
- 5944** Application of computer tomography-based 3D reconstruction technique in hernia repair surgery
Wang F, Yang XF
- 5952** Effect of methylprednisolone in severe and critical COVID-19: Analysis of 102 cases
Zhu HM, Li Y, Li BY, Yang S, Peng D, Yang X, Sun XL, Zhang M

Observational Study

- 5962** Genetic diagnosis history and osteoarticular phenotype of a non-transfusion secondary hemochromatosis
Ruan DD, Gan YM, Lu T, Yang X, Zhu YB, Yu QH, Liao LS, Lin N, Qian X, Luo JW, Tang FQ
- 5976** Abdominal ventral rectopexy with colectomy for obstructed defecation syndrome: An alternative option for selected patients
Wang L, Li CX, Tian Y, Ye JW, Li F, Tong WD
- 5988** Surgical treatment of multiple magnet ingestion in children: A single-center study
Cai DT, Shu Q, Zhang SH, Liu J, Gao ZG

Randomized Clinical Trial

- 5999** Efficacy and economic benefits of a modified Valsalva maneuver in patients with paroxysmal supraventricular tachycardia
Wang W, Jiang TF, Han WZ, Jin L, Zhao XJ, Guo Y

CASE REPORT

- 6009** Duodenal giant stromal tumor combined with ectopic varicose hemorrhage: A case report
Li DH, Liu XY, Xu LB
- 6016** Healthy neonate born to a SARS-CoV-2 infected woman: A case report and review of literature
Wang RY, Zheng KQ, Xu BZ, Zhang W, Si JG, Xu CY, Chen H, Xu ZY, Wu XM
- 6026** Pleomorphic adenoma of the trachea: A case report and review of the literature
Liao QN, Fang ZK, Chen SB, Fan HZ, Chen LC, Wu XP, He X, Yu HP
- 6036** Neoadjuvant targeted therapy for apocrine carcinoma of the breast: A case report
Yang P, Peng SJ, Dong YM, Yang L, Yang ZY, Hu XE, Bao GQ
- 6043** Huge encrusted ureteral stent forgotten for over 25 years: A case report
Kim DS, Lee SH

- 6048** Roxadustat for treatment of erythropoietin-hyporesponsive anemia in a hemodialysis patient: A case report
Yu WH, Li XJ, Yuan F
- 6056** Suspected SARS-CoV-2 infection with fever and coronary heart disease: A case report
Gong JR, Yang JS, He YW, Yu KH, Liu J, Sun RL
- 6064** Interpersonal psychotherapy-based psychological intervention for patient suffering from COVID-19: A case report
Hu CC, Huang JW, Wei N, Hu SH, Hu JB, Li SG, Lai JB, Huang ML, Wang DD, Chen JK, Zhou XY, Wang Z, Xu Y
- 6071** Optical coherence tomography angiography characteristics in Waldenström macroglobulinemia retinopathy: A case report
Li J, Zhang R, Gu F, Liu ZL, Sun P
- 6080** Forty-nine years old woman co-infected with SARS-CoV-2 and Mycoplasma: A case report
Gao ZA, Gao LB, Chen XJ, Xu Y
- 6086** Endoscopic fenestration in the diagnosis and treatment of delayed anastomotic submucosal abscess: A case report and review of literature
Zhang BZ, Wang YD, Liao Y, Zhang JJ, Wu YF, Sun XL, Sun SY, Guo JT
- 6095** Small-cell neuroendocrine carcinoma of the rectum — a rare tumor type with poor prognosis: A case report and review of literature
Chen ZZ, Huang W, Wei ZQ
- 6103** Laparoscopic left lateral sectionectomy in pediatric living donor liver transplantation by single-port approach: A case report
Li H, Wei L, Zeng Z, Qu W, Zhu ZJ
- 6110** Malignant meningioma with jugular vein invasion and carotid artery extension: A case report and review of the literature
Chen HY, Zhao F, Qin JY, Lin HM, Su JP
- 6122** Neuronal intranuclear inclusion disease mimicking acute cerebellitis: A case report
Guo JJ, Wang ZY, Wang M, Jiang ZZ, Yu XF
- 6130** Hemophagocytic lymphohistiocytosis caused by STAT1 gain-of-function mutation is not driven by interferon- γ : A case report
Liu N, Zhao FY, Xu XJ
- 6136** Single door laminoplasty plus posterior fusion for posterior atlantoaxial dislocation with congenital malformation: A case report and review of literature
Zhu Y, Wu XX, Jiang AQ, Li XF, Yang HL, Jiang WM
- 6144** Occipital nodular fasciitis easily misdiagnosed as neoplastic lesions: A rare case report
Wang T, Tang GC, Yang H, Fan JK

- 6150** Postoperative secondary aggravation of obstructive sleep apnea-hypopnea syndrome and hypoxemia with bilateral carotid body tumor: A case report
Yang X, He XG, Jiang DH, Feng C, Nie R
- 6158** Uncontrolled central hyperthermia by standard dose of bromocriptine: A case report
Ge X, Luan X
- 6164** Acute celiac artery occlusion secondary to blunt trauma: Two case reports
Li H, Zhao Y, Xu YA, Li T, Yang J, Hu P, Ai T
- 6172** Multiple ectopic goiter in the retroperitoneum, abdominal wall, liver, and diaphragm: A case report and review of literature
Qin LH, He FY, Liao JY
- 6181** Symptomatic and optimal supportive care of critical COVID-19: A case report and literature review
Pang QL, He WC, Li JX, Huang L
- 6190** Primary breast cancer patient with poliomyelitis: A case report
Wang XM, Cong YZ, Qiao GD, Zhang S, Wang LJ
- 6197** Discontinuous polyostotic fibrous dysplasia with multiple systemic disorders and unique genetic mutations: A case report
Lin T, Li XY, Zou CY, Liu WW, Lin JF, Zhang XX, Zhao SQ, Xie XB, Huang G, Yin JQ, Shen JN
- 6206** Novel triple therapy for hemorrhagic ascites caused by endometriosis: A case report
Han X, Zhang ST

ABOUT COVER

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WJCC mainly publishes articles reporting research results and findings obtained in the field of clinical medicine and covering a wide range of topics, including case control studies, retrospective cohort studies, retrospective studies, clinical trials studies, observational studies, prospective studies, randomized controlled trials, randomized clinical trials, systematic reviews, meta-analysis, and case reports.

INDEXING/ABSTRACTING

The *WJCC* is now indexed in Science Citation Index Expanded (also known as SciSearch®), Journal Citation Reports/Science Edition, PubMed, and PubMed Central. The 2020 Edition of Journal Citation Reports® cites the 2019 impact factor (IF) for *WJCC* as 1.013; IF without journal self cites: 0.991; Ranking: 120 among 165 journals in medicine, general and internal; and Quartile category: Q3.

RESPONSIBLE EDITORS FOR THIS ISSUE

Production Editor: Yan-Xia Xing; Production Department Director: Yun-Xiaojuan Wu; Editorial Office Director: Jin-Lai Wang.

NAME OF JOURNAL

World Journal of Clinical Cases

ISSN

ISSN 2307-8960 (online)

LAUNCH DATE

April 16, 2013

FREQUENCY

Semimonthly

EDITORS-IN-CHIEF

Dennis A Bloomfield, Sandro Vento, Bao-gan Peng

EDITORIAL BOARD MEMBERS

<https://www.wjgnet.com/2307-8960/editorialboard.htm>

PUBLICATION DATE

December 6, 2020

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INSTRUCTIONS TO AUTHORS

<https://www.wjgnet.com/bpg/gerinfo/204>

GUIDELINES FOR ETHICS DOCUMENTS

<https://www.wjgnet.com/bpg/GerInfo/287>

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH

<https://www.wjgnet.com/bpg/gerinfo/240>

PUBLICATION ETHICS

<https://www.wjgnet.com/bpg/GerInfo/288>

PUBLICATION MISCONDUCT

<https://www.wjgnet.com/bpg/gerinfo/208>

ARTICLE PROCESSING CHARGE

<https://www.wjgnet.com/bpg/gerinfo/242>

STEPS FOR SUBMITTING MANUSCRIPTS

<https://www.wjgnet.com/bpg/GerInfo/239>

ONLINE SUBMISSION

<https://www.f6publishing.com>



Retrospective Study

Treatment of Kümmell's disease with sequential infusion of bone cement: A retrospective study

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Author contributions: Zhang X and Li YC contributed equally to this work; Li YC, Zhou B and Yang HL designed research; Zhang X performed the surgery procedure; Li YC and Liu HP analyzed data; Zhang X, Li YC and Yang HL wrote the manuscript; All authors read and approved the final manuscript.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of Gaoyou People's Hospital Affiliated to Soochow University.

Informed consent statement: Informed written consent was obtained from the patients for publication of this manuscript and any accompanying images.

Conflict-of-interest statement: The authors declare that they have no financial or other conflicts of interest in relation to this research and its publication.

Data sharing statement: Technical appendix, statistical code, and

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Abstract

BACKGROUND

Percutaneous vertebroplasty (PVP) is an effective method for the treatment of neurologically intact Kümmell's disease, but bone cement leakage during surgery is a problem that deserves attention.

AIM

To reduce bone cement leakage and evaluate the effect of the sequential infusion of bone cement during PVP for the treatment of stage I or II Kümmell's disease.

METHODS

Patients with Kümmell's disease treated in our hospital from September 2015 to September 2018 were retrospectively analyzed. Patients meeting the inclusion and exclusion criteria were divided into two groups: Traditional single infusion and sequential infusion (SI). The visual analog scale (VAS) and Oswestry disability index (ODI) were evaluated and compared, and duration of operation, bone cement content and complications were recorded.

RESULTS

Forty-five patients were included in this study; there were 24 in the traditional single infusion group and 21 in the SI group. The VAS and ODI were significantly different for both groups when compared pre- and postoperatively, whereas the differences between 1 wk postoperatively and at the final follow-up were not statistically. When the VAS and ODI of the two groups were compared, there were no significant differences at any time point. The leakage rate of bone cement

dataset available from the corresponding author at spineinchina@163.com.

Participants gave informed consent for data sharing.

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Manuscript source: Unsolicited manuscript

Specialty type: Medicine, research and experimental

Country/Territory of origin: China

Peer-review report's scientific quality classification

Grade A (Excellent): 0
Grade B (Very good): 0
Grade C (Good): C, C
Grade D (Fair): D
Grade E (Poor): 0

Received: April 10, 2020

Peer-review started: April 10, 2020

First decision: September 24, 2020

Revised: October 6, 2020

Accepted: October 26, 2020

Article in press: October 26, 2020

Published online: December 6, 2020

P-Reviewer: Cerwenka H, Yang MS

S-Editor: Chen XF

L-Editor: Filipodia

P-Editor: Zhang YL



was significantly lower in the SI group (14.3%, 3 of 21) than that in the traditional single infusion group (41.7%, 10 of 24).

CONCLUSION

SI in unipedicular PVP is a safe and effective procedure for neurologically intact Kümmell's disease, and this technique could decrease the incidence of bone cement leakage.

Key Words: Kümmell's Disease; Percutaneous vertebroplasty; Bone cement leakage; Back pain; Osteoporosis; Intravertebral vacuum cleft

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Core Tip: Percutaneous vertebroplasty (PVP) is an effective method for the treatment of neurologically intact Kümmell's disease, but bone cement leakage during surgery is a problem that deserves attention. In our study, we found that sequential infusion in unipedicular PVP is a safe and effective procedure for neurologically intact Kümmell's disease, and this technique could decrease the incidence of bone cement leakage.

Citation: Zhang X, Li YC, Liu HP, Zhou B, Yang HL. Treatment of Kümmell's disease with sequential infusion of bone cement: A retrospective study. *World J Clin Cases* 2020; 8(23): 5887-5893

URL: <https://www.wjgnet.com/2307-8960/full/v8/i23/5887.htm>

DOI: <https://dx.doi.org/10.12998/wjcc.v8.i23.5887>

INTRODUCTION

Kümmell, in 1895, first described the triad of back pain, gradual collapse of the vertebrae and progressive kyphosis following an asymptomatic period of mild vertebral fracture^[1-3]. Patients who present with low back pain are treated with percutaneous vertebroplasty (PVP) or percutaneous kyphoplasty (PKP), which can effectively alleviate clinical symptoms and prevent continuous vertebral collapse and neurological impairment^[4-7]. Although PKP can restore vertebral height with less risk of leaking bone cement, it is cost prohibitive to many patients, especially in developing countries^[7]. In patients with intact neurological function who undergo PVP, intraoperative bone cement leakage into blood vessels can cause pulmonary artery embolism or death, and leakage into the spinal canal can compress the spinal cord or nerve roots causing severe pain or even paralysis^[5]. Therefore, a safe and effective bone cement infusion technique is essential during PVP. To reduce bone cement leakage, we adopted a sequential infusion of bone cement during PVP for the treatment of stage I or II Kümmell's disease.

MATERIALS AND METHODS

Patient selection

Patients with Kümmell's disease treated in our hospital from September 2015 to September 2018 were analyzed retrospectively. Patients were included if they met the following criteria: (1) Age \geq 55 years with T5-L5 vertebral fractures; (2) Progressive back pain and kyphosis after an asymptomatic or mild symptomatic period regardless of history of mild spinal trauma; (3) Vertebral collapse, intravertebral vacuum cleft sign and intravertebral pseudoarthrosis demonstrated on X-ray and computed tomography and "liquid sign" and "double contour sign" on magnetic resonance imaging; (4) Meet the diagnostic criteria for osteoporosis (World Health Organization), including L1-L4 bone mineral density T value $<$ -2.5 on dual-energy X-ray; (5) Stage I and II Kümmell's disease based on staging criteria proposed by Li *et al*^[8]; (6) Fractures in a single vertebral segment and receiving PVP *via* a unilateral pedicle approach; and (7) Complete initial and follow-up data.

Patients were excluded if they met the following criteria: (1) Severe medical or psychiatric disease; (2) Fresh vertebral fractures; (3) Other pathological fractures such as hemangioma, multiple myeloma and tuberculosis; (4) Neurological signs such as stage III Kümmell's disease; and/or (5) Coagulopathies. Based on the different ways of bone cement injection, patients were then divided into two groups: Traditional single infusion (TSI group) and sequential infusion (SI group, graded infusion of bone cement into the vertebra). All operations were performed by the same experienced surgeon (Zhang X).

Surgical procedure

Under digital subtraction imaging (DSA) fluoroscopy, a conventional unilateral (mainly left side) pedicle approach was used to complete PVP surgery. The operation time, bone cement content and complications were recorded.

For the TSI group, the bone cement was prepared into a filiform shape and slowly infused into the diseased vertebra under low pressure under DSA. However, in the SI group, the bone cement was prepared and infused twice into the vertebra. First, the bone cement was prepared into a late-phase filiform or early-phase mass shape and slowly infused under DSA to prevent breakage at the anterior edge of the diseased vertebra. We observed that the bone cement gradually filled the entire vertebral fracture from the outflow end without much resistance. Second, the bone cement was prepared into an early- or midphase filiform shape and infused. We observed that the bone cement adhered to the previous cement and diffused into the vertebral trabecular space until thorough diffusion was achieved.

Postoperative outcomes

On postoperative day 1, patients were able to get out of bed with waist support, and bisphosphonates and vitamin D were started to prevent osteoporosis. Patients were encouraged to get sun exposure and exercise. On the second postoperative day, bone cement leakage was evaluated using X-ray according to the method described by Wang *et al*^[9]. On direct postoperative images, the patterns of cement leakage were classified as five types: Type A, through a cortical defect into the paraspinal soft tissues; type B, through the basivertebral foramen; type C, *via* the needle channel; type D, through a cortical defect into the disc space; and type E, *via* the paravertebral vein^[9]. Patients evaluated their degree of symptom relief and improvement in activities of daily living using a visual analogue scale (VAS) and Oswestry disability index (ODI) preoperatively, 1 wk postoperatively and at their last follow-up appointment.

Statistical analysis

The SPSS 20.0 statistical software (SPSS Inc.; Chicago, IL, United States) was used for data analysis. Normally distributed data were expressed as mean \pm standard deviation and compared using a *t*-test or analysis of variance. Data not normally distributed were expressed as medians (minimum, maximum) and compared using the Mann-Whitney U test. Frequency data were expressed as percentages and compared using a Chi-square test or Fisher's exact test. Differences with a *P* value < 0.05 were considered statistically significant.

RESULTS

Forty-five patients were included in this study; this included 24 in the TSI group and 21 in the SI group. Preoperatively, all patients had chronic back pain that could not be relieved by bed rest and medical management. The baseline data in both groups are shown in Table 1. There were no significant differences in measurement indices between groups ($P > 0.05$).

Surgery was successful in all patients, and none experienced severe complications such as pulmonary embolism or spinal nerve injury. The median operation time was significantly lower in the TSI group than in the SI group (30 min *vs* 37 min, Mann-Whitney *U* test, $P = 0.000$). The bone cement was 4.5 (3.0, 5.5) mL in the TSI group and 4.0 (3.0, 5.5) mL in the SI group (Mann-Whitney *U* test, $P = 0.490$). The median follow-up period was 26 (14, 48) mo in the TSI group, and 26 (13, 49) mo in the SI group. There was no difference in follow-up duration across groups (Mann-Whitney *U* test, $P = 0.741$).

The VAS and ODI were significantly different for both groups when compared pre- and postoperatively ($P < 0.05$; Table 2), whereas the differences between 1 wk postoperatively and at the final follow-up were not statistically significant ($P > 0.05$;

Table 1 The baseline data in both groups

Variable	TSI group	SI group	P value
Number of patients	24	21	
Female/male	20/4	18/3	1.000
Age in yr, mean \pm SD	65.45 \pm 5.20	66.19 \pm 4.80	0.593
Damaged segment number, T/TL/L	3/16/5	2/15/4	0.930
BMD, mean \pm SD	-3.04 \pm 0.31	-2.96 \pm 0.28	0.335

Note: Statistical significance was set at $P < 0.05$. BMD: Bone mineral density; L: Lumbar region; SD: Standard deviation; SI: Sequential infusion; T: Thoracic region; TL: Thoracolumbar region; TSI: Traditional single infusion.

Table 2 Visual analog scale and Oswestry disability index before and after surgery

Variable	TSI group	SI group	P value
VAS, M, min, max			
Preoperatively	6 (5, 8)	6 (5, 8)	0.576
1 wk postoperatively	2 (1, 3) ¹	2 (1, 3) ¹	0.868
At final follow-up	2 (1, 3) ¹	2 (1, 3) ¹	0.785
ODI, %, mean \pm SD			
Preoperatively	65.42 \pm 3.26	64.54 \pm 4.56	0.421
1 wk postoperatively	30.55 \pm 1.79 ¹	30.54 \pm 2.98 ¹	0.981
At final follow-up	29.44 \pm 1.56 ¹	28.65 \pm 1.94 ¹	0.139

¹Indicates significant differences in comparison with preoperative values (statistical significance was set at $P < 0.05$). M: Median; Max: Maximum; Min: Minimum; ODI: Oswestry disability index; SD: Standard deviation; SI: Sequential infusion; TSI: Traditional single infusion; VAS: Visual analog scale.

Table 2). When the VAS and ODI of the two groups were compared, there were no significant differences at any timepoint ($P > 0.05$; **Table 2**).

In the TSI group, the total leakage rate of bone cement was 41.7%. There were four cases of leakage into the paravertebral soft tissue *via* the bone cortical defect, two cases of basivertebral foramen leakage and four cases of intervertebral disc space leakage, without obvious clinical symptoms. In the SI group, the total leakage rate of bone cement was 14.3%. There were three cases of intervertebral disc space leakage, without obvious clinical symptoms. The leakage rate of bone cement was lower in the SI group than in the TSI group (Pearson chi-squared test, $P = 0.043$).

DISCUSSION

Even though Kümmell's disease is common and has low morbidity when recognized, it often remains undiagnosed because it is mistaken as osteoporotic vertebral compression fractures. Kümmell's disease was actually not accepted as a condition until 1951 when delayed vertebral collapse was discovered on X-ray^[10]. With the widespread use of imaging, increasingly more clinicians have begun to diagnose the disorder and report it^[5,11-14].

Kümmell's disease develops progressively. The vertebral body is intact or slightly fractured in the early stage, vertebral collapse and instability occur in the middle stage and there is obvious vertebral collapse and progressive kyphosis in the later stage^[1-3,14]. In this study, patients in both groups had chronic disease, and they still had persistent back pain after nonsurgical treatment. Nonsurgical managements such as analgesia, immobilization and bed rest are ineffective for Kümmell's disease, and long-term bed rest is also harmful to elderly patients. Therefore, surgical intervention should be performed as early as possible for patients with Kümmell's disease to prevent further vertebral collapse and kyphosis.

With the development of minimally invasive spinal surgery, PVP and PKP have gradually been used in the treatment of Kümmell's disease to stabilize the vertebral body and decrease pain^[4-7]. In this study, Kümmell's disease was treated with PVP *via* the vertebral pedicle unilaterally in both groups, achieving satisfactory clinical efficacy. The VAS and ODI were significantly different in both groups pre- and postoperatively. At the final follow-up, the VAS and ODI were not significantly different in either group compared with those at 1 wk postoperatively. The two groups were not significantly different for the VAS and ODI pre- and postoperatively or at the final follow-up. These results demonstrate that both sequential infusion and one-time infusion of bone cement can effectively stabilize the vertebral body and eliminate the micromovement of the fracture block, leading to a positive analgesic effect.

During the PVP operation, bone cement leakage into blood vessels can cause pulmonary artery embolism or death, and leakage into the spinal canal can compress the spinal cord or nerve roots causing severe pain or even paralysis^[5]. Therefore, it is of great significance to reduce and avoid bone cement leakage during PVP surgery. Compared with osteoporotic vertebral compression fractures, the main complication of treating Kümmell's disease with PVP is bone cement leakage, with the leakage rate being far higher than in patients with osteoporotic vertebral compression fractures without Kümmell's disease^[6]. Peh *et al*^[5] reported that the leakage rate of bone cement in PVP for Kümmell's disease can be up to 79%, which may be related to vertebral rupture. Ha *et al*^[6] demonstrated that in the treatment of osteoporotic vertebral fracture patients with an intravertebral cleft sign, the leakage rate of bone cement in PVP is 75%.

The vertebral anterior wall is mostly ruptured in Kümmell's disease, so bone cement leakage occurs easily in PVP. In order to prevent bone cement leakage from the rupture point of the vertebral anterior wall and improve the safety of surgery, we performed sequential infusion and found that the leakage rate of bone cement was significantly lower (14.3%) than that in TSI group (41.7%). In the SI group, there were three cases of bone cement leakage but not from the rupture mouth at the anterior edge of the vertebral body, suggesting that the graded infusion of bone cement can effectively prevent bone cement leakage from the rupture mouth of the vertebral anterior wall. In the SI group, the push rod was pressed as closely as possible to the fracture at the anterior edge of the vertebral body, and the higher viscosity bone cement was slowly infused to first block the fracture. Then the lower viscosity bone cement was infused so that it could disperse in the vertebral body. However, the operation time in the SI group was longer than in the TSI group. In addition, the leakage rate of bone cement in both groups was lower than reported in the literature, and the possible reason is that the infusion of bone cement was continuously monitored with the aid of DSA.

In patients with Kümmell's disease, there are liquid or gas cavities in the vertebral body. During infusion, the bone cement can flow freely without resistance and fill the entire cavity symmetrically. In this study, therefore, the bone cement was infused into the entire vertebral body *via* the unilateral vertebral pedicle without bilateral puncture.

Wang *et al*^[15] reported a case of delayed bone cement displacement after treatment of Kümmell's disease with PKP, leading to progressive back pain. The possible reason for the displacement is that rupture and collapse of loose trabecular bone may have occurred during balloon dilatation, forming high-density bone. In the secondary infusion, the bone cement may have poorly dispersed and failed to adhere, resulting in bone cement displacement. In this study, there was no displacement of the bone cement in either of the two groups, which may have been due to diffusion into the honeycomb-shaped bone during PVP so that the bone cement was firmly fixed in the vertebral body.

A limitation of this study is that it is retrospective and may be prone to selection bias. However, bias is limited through strict inclusion and exclusion criteria and matching of patients. Second, the sample size was small and the follow-up period was short in both groups. Finally, the specific condition of bone cement leakage after PVP was not evaluated *via* computed tomography imaging.

CONCLUSION

This study indicates that sequential infusion in unipedicular PVP is a safe and effective procedure for neurologically intact Kümmell's disease. This technique could decrease the incidence of bone cement leakage.

ARTICLE HIGHLIGHTS

Research background

Percutaneous vertebroplasty (PVP) is an effective method for the treatment of neurologically intact Kümmell's disease, but bone cement leakage during surgery is a problem that deserves attention.

Research motivation

To reduce bone cement leakage and evaluate the effect of the sequential infusion of bone cement during PVP for the treatment of stage I or II Kümmell's disease.

Research objectives

To compare the clinical effect of sequential bone cement infusion and traditional bone cement infusion in the treatment of stage I or II Kümmell's disease.

Research methods

Patients with Kümmell's disease treated in our hospital from September 2015 to September 2018 were retrospectively analyzed. Patients meeting the inclusion and exclusion criteria were divided into two groups: Traditional single infusion (TSI group) and sequential infusion (SI group). The visual analog scale (VAS) and Oswestry disability index (ODI) were evaluated and compared, and duration of operation, bone cement content and complications were recorded.

Research results

Forty-five patients were included in this study, 24 in the TSI group and 21 in the SI group. The VAS and ODI were significantly different in both groups pre- and postoperatively. At the last follow-up, the VAS and ODI were not significantly different between the two groups compared with those at 1 wk postoperatively. The two groups had no significant differences in the VAS and ODI pre- and postoperatively and at the last follow-up. The leakage rate of bone cement was significantly lower in the SI group (14.3%, 3 of 21) than that in the TSI group (41.7%, 10 of 24).

Research conclusions

Sequential infusion in unipedicular PVP is a safe and effective procedure for neurologically intact Kümmell's disease, and this technique could decrease the incidence of bone cement leakage.

Research perspectives

The role of sequential infusion in reducing the leakage of bone cement should be evaluated in a large sample multicenter randomized controlled study.

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