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Robot-Assisted Versus Fluoroscopy-Assisted Kyphoplasty in the Treatment of Osteoporotic Vertebral Compression Fracture: A Retrospective Study

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Abstract

Study design: A retrospective study.

Objectives: To compare the clinical and radiological outcomes of robot assisted (RA) and fluoroscopy assisted (FA) percutaneous kyphoplasty (PKP) in treating single/double segment osteoporotic vertebral compression fracture (OVCF).

Methods: Patients with single/double segment OVCF receiving either RA or FA PKP were evaluated retrospectively at our spine center from April 2018 to October 2019. The operation time, fluoroscopy frequency, fluoroscopy exposure time, total radiation dose, visual analogue scale (VAS), local kyphosis angle (LKA), height of fractured vertebra (HFV) and complications were compared between the single/double RA group and the FA group.

Results: A total of 96 cases were included in this study, with 59 cases of single segment OVCF and 37 cases of double segment OVCF. For single/double segment OVCF, both RA and FA PKP could relieve pain and reduce fracture. The RA group showed lower fluoroscopy frequency, shorter fluoroscopy exposure time during operation for surgeons, better correction in LKA and HFV, lower rate of cement leakage, but more fluoroscopy frequency, fluoroscopy exposure time and radiation dose for patients compared with the FA group ($P < 0.05$), while the single RA group showed longer operation time compared with the FA group ($P < 0.05$).

Conclusions: For single/double segment OVCF, RA has more advantages in correcting vertebra fracture, reducing intraoperative radiation exposure for surgeons, and reducing the cement leakage rate, but it increases intraoperative radiation for patients compared with FA PKP. And FA has shorter operation time in treating single segment OVCF than RA PKP.

Keywords

percutaneous kyphoplasty, robot, osteoporotic vertebral fracture

Introduction

Osteoporotic vertebral compression fracture (OVCF) often causes back pain and limited mobility, which has a high rate of disability and mortality and has become an important social problem affecting the health of the elderly.[1] Percutaneous kyphoplasty (PKP), as a minimally invasive vertebral augmentation technique, could greatly improve the quality of life for patients with OVCF and has become one of the main treatments for OVCF.[2,3]

Complications like puncture injury and bone cement leakage during PKP could happen even with experienced surgeons.[4,5] The extensive application of 3D fluoroscopy-based CT,[6] 3D printing guide template,[7] real-time ultrasound,[8] augmented reality,[9] and other navigation technologies to assist PKP surgery

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could increase puncture accuracy, decrease puncture-related complications, shorten surgical time and yield less radiation exposure.

Recently, robots have been emerging to assist pedicle screw placement in spine surgeries, and clinical studies reveal that they could significantly improve the accuracy of pedicle screw placement compared with the conventional fluoroscopy.[10] The advantages of robots over navigation techniques include preventing tremor, avoiding unstable factors due to human hand manipulation, further improving spine surgery accuracy and being minimally invasive.[11] So far, there are few reports on the clinical outcomes of robot assisted PKP surgery.[12,13] In the current study, we retrospectively analyzed the patients with single/double segment OVCF treated with either robot assisted (RA) or fluoroscopy assisted (FA) PKP and compared the clinical and radiological outcomes, aiming to figure out whether there is benefit of RA PKP for treating OVCF.

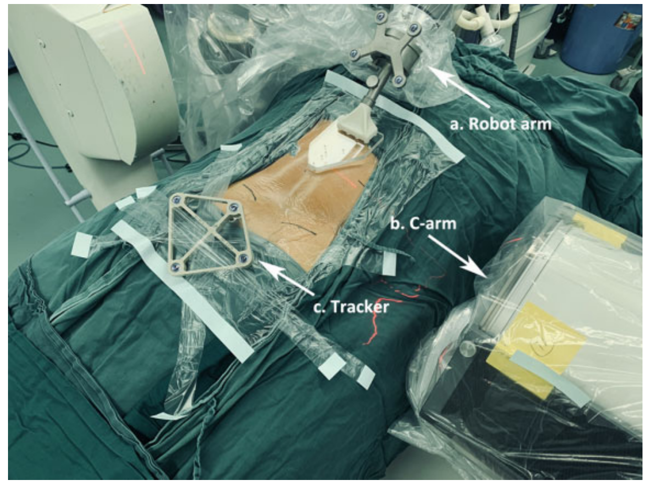

Figure 1. The robot arm (a), C-arm (b) and tracker (c).

Materials and Methods

Patient Population

This is a retrospective study, and the OVCF patients treated with PKP at our spine center from April 2018 to October 2019 were evaluated. The approval for this study was obtained from the Institutional Review Board of our hospital (No. 2018-254-2). Written informed consent was obtained from all the patients before conducting any procedures.

The inclusion criteria were: (1) age ≥55 years old; (2) bone density T ≤ -2.5; (3) imaging showed single or double segments vertebral fracture;(4) moderate or severe back pain associated with fracture segment, which affects the patient's daily activities and with poor response to non-surgical therapy; (4) treated with robot assisted or fluoroscopy assisted PKP. The exclusion criteria were: (1) vertebral body tumors, vertebral infection, metastatic bone disease, kummell disease or old healed vertebral fracture with normal signal intensity on MRI sequences; (2) combined with neurological symptoms; (3) severe physical conditions.

Data Collection

Detailed information was obtained from the medical records. Demographic data were collected, including age, gender, fracture segment distribution, and time interval from injury to operation.

Operation time, fluoroscopy frequency, fluoroscopy exposure time, total radiation dose of C-arm output, the visual analogue scale (VAS), the local kyphosis angle (LKA), height of fractured vertebra (HFV) and complications were also collected. The local kyphosis angle was defined as the angle formed by lines drawn parallel to the caudal and cranial fractured endplates in lateral X-ray radiograph. HFV was measured at the most compressed point (anterior or middle) of the vertebral endplate using lateral X-ray radiograph. Complications like cement leakage, infection, nerves or blood vessels injury and fracture in adjacent levels were recorded.

Surgical Intervention

All PKP surgical procedures were performed by the same group of surgeons in a single institution. Under general anesthesia, a prone position was taken and the vertebra was punctured unilaterally. All the patients before surgery were prescribed with bed rest and analgesic and anti-osteoporosis drugs.

For robot assisted PKP, the robot applied in the current study was TiRobot® system (Tinavi Medical Technologies Co., Beijing, China), which consists of an optical tracking device, a surgical planning and controlling workstation and a surgical robotic arm. The robotic arm has 6 degrees of freedom guide implantation of K-wire or screw accurately planned by surgeons. This robot was also applied in our previous study.[13] Firstly, the tracker was stably fixed on the surface of the patient with sterile tape, and the robot arm was covered with a sterile sheath, followed by adjusting the end-positioning ruler of the robot arm so that the marker points were located in the X-ray fluoroscopy field (Figure 1). Secondly, after 3-dimensional scanning performed in a 190 circuit with the C-arm (Arcadis Orbic 3D, Siemens), the unilateral puncture trajectory was planned to optimize the position on the robot surgical planning and controlling workstation. Thirdly, K-wire was drilled into the vertebral body percutaneously by robot assisted skin surface positioning technique, and the position of the K-wire was verified under the C-arm fluoroscopy. Any deviation shall be adjusted in time. After confirming the position of K-wire, the working channel of PKP was established.

For the fluoroscopy assisted PKP, anterioposterior and lateral fluoroscopy by C-arm was performed to mark the skin projection of the pedicle of the injured vertebra, and an incision of 0.5 cm at around 2 cm outer edge of pedicle projection was made. A unilateral puncture route was taken with an abduction angle around 30°. When the Jamshidi trocar end touched bone surface, the position of trocar was verified with C-arm fluoroscopy. If it was not in a good position, the trocar was adjusted under the C-arm fluoroscopy. Then trocar was hit along the pedicle into the vertebra. A deflated balloon (KMC, Shanghai, China) was inserted into the vertebral body and inflated to restore the height of the collapsed vertebral body and create an internal cavity under manometric control. Polymethyl methacrylate (PMMA) cement was slowly injected at appropriate intervals and low pressure under fluoroscopy to make the cement diffuse into the vertebral body. The process was stopped timely when the bone cement reached the posterior wall of the vertebral body or the extraosseous space.

After the surgery, vital signs were monitored within 6 hours, and exercise of lower extremities while lying in bed was recommended. The patients were allowed to walk 24 hours after the operation with a brace and received an X-ray examination. Systematic anti-osteoporosis drug treatment was continued after discharge from the hospital.

Statistical Analysis

Data analysis was performed using SPSS 20.0 (IBM, New York, USA). G*Power 3.1 software was used to calculate the power of test.[14] Measurement data were presented as mean $\pm$ standard deviation (SD), and t test was used for the measurement data such as age, operation time, fluoroscopy frequency and time, etc. Chi-square test was used to compare the categorical data such as sex, fracture segment distribution, complications rate. $P < 0.05$ was considered statistically significant.

Results

A total of 96 patients were included in this study, including 9 males and 87 females, with an average of 70.3 years (55-91 years). All the patients had minor or no trauma history. X-ray, CT, MRI and bone mineral density examinations were performed before surgery. 59 patients had single-segment fractures, and 37 of the 59 patients (62.7%) received robot assisted PKP (single RA group), while 22 of the 59 patients (37.3%) received fluoroscopy assisted PKP (single FA group), and the statistic power was 0.83 with this sample size. 37 patients had double-segments fractures, and 21 of the 37 patients (56.8%) received robot assisted PKP surgery (double RA group), and 16 of the 37 patients (43.2%) received fluoroscopy assisted PKP surgery (double FA group), and the statistic power was 0.65 with this sample size. There was no statistically significant difference in terms of gender, age, distribution of injured vertebral segments and the time interval from symptom onset to operation in the patients with single/double-segments fractures between RA and FA group ($P > 0.05$). All the cases were followed up for 6 months. The baseline data of the patients with single segment OVCF were summarized in Table 1, and the baseline data of the patients with double segments OVCF were summarized in Table 2.

Table 1. Baseline Data of the Patients With Single Segment OVCF.

	Single RA (37 patients, 37 segments)	Single FA (22 patients, 22 segments)
Gender, Female (%)	34(91.9%)	19(86.4%)
Age, years, mean (SD)	69.9(8.7)	73.4(8.4)
BMD, T score (mean)	-2.9(0.5)	-3.0(0.5)
Distribution of fracture vertebra, n (%)		
T5-T9	6(16.2%)	3(13.6%)
T10-L2	25(67.6%)	16(72.6%)
L3-L5	6(16.2%)	3(13.6%)
Time interval between symptom onset and operation, days, mean (SD)	10.5(4.6)	11.1(4.3)

BMD, bone mineral density.

Table 2. Baseline Data of the Patients With Double Segments OVCF.

	Double RA (21 patients, 42 segments)	Double FA (16 patients, 32 segments)
Gender, Female (%)	19(90.5%)	14(87.5%)
Age, years, mean (SD)	71.5(9.0)	70.3(8.1)
BMD, T score, mean (SD)	-3.1(0.6)	-2.9(0.4)
Distribution of fracture vertebra, n (%)		
T5-T9	9(21.4%)	3(9.4%)
T10-L2	27(64.3%)	24(75%)
L3-L5	6(14.3%)	5(15.6%)
Time interval between symptom onset and operation, days, mean (SD)	9.5(4.2)	10.1(4.3)

BMD, bone mineral density.

Tables 3 and 4 summarized the clinical and radiological results of the single/double RA and FA group. In terms of operation parameters, the mean operation time was 45.3 $\pm$ 6.5 mins in the single RA group, longer than that of 36.5 $\pm$ 5.7 mins in the single FA group ($p < 0.05$). There was no significant difference between the double RA group (46.6 $\pm$ 7.1 mins) and the double FA group (44.5 $\pm$ 6.6 mins), $P > 0.05$. During the 60 secs of 3D scanning with C-arm in the RA group, surgeons could stay out of the operation room. Hence the fluoroscopy exposure time and frequency in the single/double RA group for surgeons were significantly lower than these in the FA group. And for the patients, the fluoroscopy exposure time and frequency were significantly higher than these in the FA group ($P < 0.05$). The fluoroscopy exposure time in the single RA was 20.5 $\pm$ 3.9 secs for the surgeons and 80.5 $\pm$ 3.9 secs for the patients, while the fluoroscopy exposure time in the single FA group was 31.7 $\pm$ 5.3 secs. In the double RA, the fluoroscopy exposure time was 23.4 $\pm$ 4.1 secs for the surgeons and 83.4 $\pm$ 4.1 secs for the patients, and in the double FA group, it was 39.1 $\pm$ 6.7 secs. The fluoroscopy frequency in the single RA was 15.8 $\pm$ 3.6 for the surgeons and 115.8 $\pm$ 3.6 for the patients, and that in the single FA group was 22.6 $\pm$ 4.5. The fluoroscopy frequency in the double RA was 17.2 $\pm$ 4.1 for

Table 3. Main Results of the Patients With Single Segment OVCF.

	Single RA (37 patients, 37 segments)	Single FA (22 patients, 22 segments)	P
Operation time, min, mean (SD)		36.5(5.7)	<0.05
Fluoroscopy exposure time, sec, mean (SD)	Patient:80.5(3.9)	31.7(5.3)	<0.05
	Surgeron:20.5(3.9)		<0.05
Fluoroscopy frequency, n, mean (SD)	Patient:115.8(3.6)	22.6(4.5)	<0.05
	Surgeron:15.8(3.6)		<0.05
Total radiation dose of C-arm output, mGy, (SD)	113.9(37.5)	94.3(26.2)	<0.05
VAS, mean (SD)			
Preoperation	6.9(1.3)	7.1(1.7)	>0.05
1 day postoperation	2.0(1.1)*	2.2(0.9)*	>0.05
6 months postoperation	1.3(0.9)*#	1.6(0.8)*#	>0.05
LKA, °, mean (SD)			
Preoperation	12.7(4.1)	12.2(4.3)	>0.05
1 day postoperation	4.8(3.1)*	7.5(3.4)*	<0.05
6 months postoperation	5.2(3.2)*	8.1(3.7)*	<0.05
HFV, cm, mean (SD)			
Preoperation	1.6(0.4)	1.5(0.3)	>0.05
1 day postoperation	2.2(0.5)*	1.9(0.5)	<0.05
6 months postoperation	2.1(0.4)*	1.8(0.3)	<0.05
Cement leakage, % (n/n)	8.1(3/37)	27.3(6/22)	<0.05
Intradiscal	1	2	
Anterior/lateral vertebra	2	4	

*Compared with preoperation, P < 0.05.
#Compared with 1 day postoperation, P < 0.05.
VAS, visual analogue scale; LKA, local kyphosis angle; HFV, height of fractured vertebra.

Table 4. Main Results of the Patients With Double Segments OVCF.

	Double RA (21 patients, 42 segments)	Double FA (16 patients, 32 segements)	P
Operation time, min,mean(SD)	46.6(7.1)	44.5(6.6)	>0.05
Fluoroscopy exposure time,sec,mean(SD)	Patient:83.4(4.1)	39.1(6.7)	<0.05
	Surgeron:23.4(4.1)		<0.05
Fluoroscopy frequency,n,mean(SD)	Patient:117.2(3.4)	31.6(5.6)	<0.05
	Surgeron:17.2(3.4)		<0.05
Total radiation dose of C-arm output, mGy, (SD)	135.7(38.6)	110.4(28.3)	<0.05
VAS,mean(SD)			
Preoperation	7.4(1.5)	7.2(1.9)	>0.05
1 day postoperation	2.5(1.3)*	2.4(1.1)*	>0.05
6 months postoperation	1.1(0.7)*#	1.3(0.8)*#	>0.05
LKA,°, mean(SD)			
Preoperation	11.7(4.4)	12.6(4.6)	>0.05
1 day postoperation	5.3(3.1)*	8.5(3.5)*	<0.05
6 months postoperation	5.5(3.4)*	9.2(4.1)*	<0.05
HFV, cm, mean(SD)			
Preoperation	1.6(0.3)	1.5(0.3)	>0.05
1 day postoperation	2.2(0.5)*	1.8(0.4)	<0.05
6 months postoperation	2.0(0.3)*	1.7(0.4)	<0.05
Cement leakage,%(n/n)	9.5(4/42)	28.1(9/32)	<0.05
Intradiscal	2	4	
Anterior/lateral vertebra	2	5	

*Compared with preoperation, P < 0.05.
#Compared with 1 day postoperation, P < 0.05.
VAS,visual analogue scale; LKA, local kyphosis angle; HFV, height of fractured vertebra.

surgeons and 117.2 ± 4.1 for patients, and that in the double FA group was 31.6 ± 5.6. The mean total radiation dose of C-arm output to the patients during the whole procedure was 122.9 ± 37.5 mGy in the single RA group, 94.39 ± 26.2 mGy in the single FA group (P < 0.05), 135.7 ± 38.6 mGy in the double RA double and 110.2 ± 28.3 mGy in the double FA group (P < 0.05).

The VAS scores decreased significantly after PKP in the single/double RA or FA groups (P < 0.05), but there was no significant difference between the groups (P > 0.05). The VAS at the 6th month follow-up was 1.3 ± 0.9 in the single RA group, 1.6 ± 0.8 in the single FA group, 1.1 ± 0.7 in the double RA group and 1.3 ± 0.8 in the double FA group (P > 0.05). The LKA and HFV were corrected significantly after PKP in the single/double RA or FA groups, and the RA group showed better correct compared with the FA group (P < 0.05).The mean LKA and HFV at the 6th month follow-up were 5.2 ± 3.2° and 2.1 ± 0.4 cm in the single RA group, 8.1 ± 3.7° and 1.8 ± 0.3 cm in the single FA group (P < 0.05), 5.5 ± 3.4° and 2.0 ± 0.3 cm in the double RA group, 9.2 ± 4.1° and 1.7 ± 0.4 cm in the double FA group (P < 0.05).

In terms of complications, there was no mortality or major morbidity case, for example, infection, embolism, and neurological or vascular injury. The main intraoperative complication was bone cement leakage. The leakage incidence was 8.1% (3/37) in the single RA group, 27.3% (6/22) in the single FA group (P < 0.05), 9.5% (4/42) in the double RA group, and 28.1% (9/32) in the double FA group (P < 0.05). All the cases of cement leakage happened at the disc space or anterior/lateral vertebra.

Discussion

Robot assistance in spine surgeries has merits of improving the accuracy in orientation and guidance of implant placement according to the surgery plan. So far, well-studied spine robots mainly include "SpineAssist®/Renaissance®" (Mazor Robotics Ltd., Caesarea, Israel) approved by US Food and Drug Administration (FDA) in 2004.[15,16] "ROSA® spine" (Medtech, Montpellier, France) with US FDA clearance in 201 6[17] and "TiRobot®" approved by China FDA in 2016.[11] Several studies have shown that these spine robots can improve the accuracy of pedicle screw placement, with the accuracy rate of screw placement within the pedicle for "Renaissance®" robots to be 93.7%,[18] "Rosa®" to be 89.2%[19] and "TiRobot®" to be 95.3%.[20] While according to a recent meta-analysis of robot-assisted versus fluoroscopy assisted freehand technique in spine surgery, which included 5 randomized controlled trials (RCTs) of Renaissance® and 2 RCT of TiRobot®, TiRobot® assistance is more accurate in screw positions than the fluoroscopy assisted freehand technique, and Renaissance® assisted technique had the same accuracy as the freehand technique in screw positioning. Based on the accuracy and safety of the robot, there have been a few preliminary attempts to treat OVCF with robot assisted PKP, but the clinical and radiological outcomes are yet to be revealed. In our previous study on the learning curve of robot assisted PKP, we found that the accuracy of robot puncture was 95.8% and puncture accuracy did not change with the increase in the number of operations.[13] In the current retrospective study, we further compared robot assisted and fluoroscopy assisted PKP in treating single/double-segment OVCF, and we found that robot was superior to fluoroscopy in certain aspects.

PKP can well correct kyphosis, restore vertebral height and relieve pain in OVCF patients.[4] All the patients in the current study showed notable correction in local kyphosis angle and restoration of vertebral height after PKP. In addition, the single/double RA group had the advantage over the single/double FA group in improving local kyphosis angle and vertebral height. So far, few studies of navigation technique assisted PKP reported the restoration of compressed vertebrae. Alsalmi et al[21] studied "ROSA®" robot-assisted intervertebral augmentation, and the results showed that the mean degree of residual local kyphosis (4.7°) and the percentage of vertebral body height restoration (63.6%) were significantly better after RA than these after FA technique (8.4° and 30%, respectively), but the authors did not explain the reason why the RA could correct more kyphosis and vertebral body height than the FA technique. Zhang et al[22] compared OVCF patients receiving O-arm 3D reconstructed intraoperative images navigation assisted PKP with fluoroscopy assisted PKP, and they reported that there was no difference in the restoration of the compressed vertebrae. In this study, all the patients received unilateral puncture. In the FA group, surgeons mainly relied on the anatomical landmarks to adjust the puncture angle, and the transpedicular puncture angles varied from 20 to 40 degrees in the horizontal plane depending on different vertebralsegments.[23] The puncture abduction angle could be hardly controlled in the FA group, especially when the spine is combined with deformity due to scoliosis or spondylolisthesis and the balloon could not be placed over the vertebral midline. While in the RA group, the balloon can be placed over vertebral midline or the most collapse vertebral body, which is the main reason of better reduction of the fractured vertebral body in the RA group. In addition, even though we did not record the amount of cement injected in each fractured vertebra, the underlying amount difference in injection may be another reason. It's also notable that the correction of fractured vertebral kyphosis and height after PKP may lose over time.[3,24] In this study, despite that some patients at the 6th month follow-up presented vertebral body height recollapse, there was no significant difference compared with 1 day after PKP, and long-term follow-up would be necessary.

PKP could provide immediate OVCF pain relief, but the mechanism of the pain relief is not fully clear, which may involve thermal necrosis, chemical toxicity, neurotoxicity to the pain receptors in bone and stability reconstruction of the vertebral body.[25] In addition, the correction of kyphosis after PKP plays an important role in long-term pain relief.[26] In the current study, we found that VAS reduced significantly after PKP, and there was no difference between the RA group and the FA group at 1 day and 6 months after PKP, despite that the RA group showed better kyphosis correction than the FA group. The reason for the no difference in VAS could be the short follow-up duration, as the advantage of robot correction of kyphosis might not be reflected by the VAS score. In other navigation technique assisted PKP studies, the VAS improved dramatically after surgery without difference compared with FA group.[21,22]

Radiation exposure during operation is an occupational risk for orthopedic surgeons. Mastrangelo et al[27] found that orthopedic surgeons have a high incidence of tumor due to radiation exposure. In spine surgeries, X-ray fluoroscopy is often needed to determine the implant path, which would undoubtedly increase the risk of radiation exposure for surgeon. The application of spinal robot is expected to reduce such risk of occupational exposure. It has been reported that "SpineAssist®" and "Rosa®" spinal robot assisted PKP can reduce the radiation exposure of surgeons or patients compared with fluoroscopy assisted PKP surgery during the operation.[12,21] The "TiRobot®" robot in lumbar spinal instrumentation surgery could reduce the radiation exposure of surgeons, but it may increase the radiation exposure of patients.[28] In the current study, we found that the patients in the RA group received significantly higher fluoroscopy frequency, longer exposure time and higher total radiation dose than those in the FA group. As the surgeons could be away from the radiation area during the 3D scanning by the C-arm in operation, the actual radiation exposure surgeons received was significantly lower than that in the FA group. Other robots like "SpineAssist®" and "Rosa®" require preoperative CT images to be uploaded to the robots, and during the operation, anterior-posterior/oblique fluoroscopy is used for registration,[29] which could decrease the intraoperative radiation, while "TiRobot®" robot requires the intraoperative 3D scan CT for registration. Such difference in registration design of different robots could account for the difference in radiation exposure between the surgeons and patients. The issue that the patients in this study experienced an increased radiation exposure should not be easily overlooked. In order to decrease the intraoperation exposure, the robot software shall be improved to perform navigation without intraoperative 3D CT scanning, which contributes to a higher dose to the patient. In addition, gland radiation protection of patients could be considered during operation.

The operation time is one of the main indications of surgical trauma. Reports on the operation time of the RA spinal surgery vary depending on the type of disease. Han et al[20] reported that the operation time of RA thoracolumbar spine internal fixation surgery was 149.5 $\pm$ 50.8 mins, which was slightly longer than that of the FA of 138.0 $\pm$ 48.6 mins, but there was no statistical difference between the 2 methods. However, Alsalmi et al[21] reported that RA intravertebral augmentation was 52 $\pm$ 11 mins, which was significantly longer than that of C-arm assisted surgery of 30 $\pm$ 11 mins. In this study, the operation time of RA surgery for single segment fractures was significantly longer than that of the FA surgery. This is due to the extra preparation time for the surgical robot. Our previous research revealed that the preparation time of the robot was about 20 mins.[13] For double segments fractures, the FA puncture might require repeated adjustments when the position of puncture is inappropriate, which could increase the operation time. While the RA puncture can achieve the double-segment positioning puncture in one time, and there was no significant difference in double-segments groups. Therefore, we propose that the robot has more advantages in the operation time for treating multi-segments fractures.

The leakage of bone cement after PKP is a problem that remains to be solved. It is reported that the incidence of bone cement leakage varies from 4.8% to 39%.[4] In this study, we observed that the cement leakage rate in the single/double RA was 7.7% and 9.5%, while that in the in single/double FA was 27.3% and 28.1%, with a statistical difference between RA and FA groups. A variety of improved bone cement injection techniques could reduce the leakage rate, including sequential injection of bone cement, secondary expansion of the balloon, fill with gelatin sponge, etc.[4,30] Among these prevention strategies, we believe that an accurate puncture in the vertebral body is the most basic and important strategy. In our previous study, we found that the success rate of RA puncture was 95.8% which was significantly higher than that of 63.2% in FA group.[13] We believe the application of robot can achieve accurate vertebral puncture, reduce the risk of pedicle damage, place the balloon in the middle of the vertebral body or the most severe site of fracture collapse, thereby forming a bone cement perfusion cavity, improving the bone density at the fracture site, and reducing the risk of bone cement leakage.

In this study, we comprehensively compared the RA or FA PKP for treating single/double segments OVCF. There are some limitations in this study: (1) this is a single center retrospective study, and its credibility could be affected by the accuracy of the data retrieved from the medical records, and there was no randomization in deciding the type of treatment. Also there was an absence of blinding of the surgeon and blinding of evaluating the outcomes, and the validity of this study remains to be evidenced by further prospective studies; (2) the small sample size in double segments fracture groups presented moderate statistic power, which may cause unreliability of statistical results, and further study with large sample size is needed; (3) the long-term postoperative complications, such as subsequent vertebral fracture was not observed due to a limited follow-up duration; (4) a cost-effective analysis of the technique was not performed.

Conclusions

RA and FA PKP showed similar results in terms of pain relief for treating OVCF. For single/double segments OVCF, RA has more advantages in correcting vertebra fracture, reducing intraoperative radiation exposure of surgeons, and reducing the cement leakage rate, but it could increase intraoperative radiation for patients. In terms of the operation time, FA has more advantages in treating single segment fracture, but shows similar results with RA in treating double segments OVCF. Therefore, we believe that RA PKP is more suitable for treating multisegment OVCF.

Declaration of Conflicting Interests

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