A Retrospective Evaluation of Operative and Postoperative Outcomes in Patients with Spinal Metastases from a Single Center to Compare Vertebrectomy with Combined Vertebrectomy and Radiofrequency Ablation

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Background: This retrospective study was conducted at a single center and aimed to evaluate operative and postoperative outcomes in patients with spinal metastases using vertebrectomy and combined vertebrectomy and radiofrequency ablation (RFA).

Material/Methods: Patients diagnosed with spinal metastases between April 2009 and March 2016 (n=49) included patients who underwent vertebrectomy (n=26) and patients who underwent combined vertebrectomy and RFA (n=23). The characteristics of the 2 groups were similar in primary tumor types, comorbidities, Tomita score, vertebral involvement, preoperative bone pain, and neurologic deficit.

Results: The results showed for both groups that the visual analog scale (VAS) pain score was significantly decreased (P<0.05) and the neurological status was improved after treatment. Compared with the control group (vertebrectomy only), the combination group (combined vertebrectomy and RFA) had less intraoperative blood loss (P=0.002) and shorter operation time (P<0.001). The recurrence rate was lower (P=0.003) in the patients who received combined treatment, and the period of local recurrence was prolonged (P=0.030) in the combination group.

Conclusions: This retrospective study showed that the selective use of combined vertebrectomy and RFA significantly reduced surgical time and blood loss, improved recovery of neurologic deficit, and reduced the tumor recurrence rate in patients with spinal metastases.

Keywords: Orthopedic Procedures • Radiofrequency Ablation • Spine

Abbreviations: RFA – radiofrequency ablation; VAS – visual analog scale; MESCC – metastatic epidural spinal cord compression; TES – total en-bloc spondylectomy; CT – computed tomography; MRI – magnetic resonance imaging

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Background

For the arterial system and the valveless venous plexus of Batson, 36-55% of patients with primary cancers such as breast cancer, lung cancer, prostate cancer, renal cancer, thyroid cancer, gastrointestinal cancer, or multiple myeloma develop spine diseases, resulting in spinal column involvement or intramedullary spinal cord metastases [1-4]. Patients with metastatic spinal tumors usually show symptoms of bone pain, spinal cord compression, pathologic fracture, hypercalcemia, and progressive deformity. In addition to creating neurologic deficits, the symptoms seriously worsen the quality of life and reduce survival [5]. The rate of spinal cord compression due to epidural metastases is approximately 5-10%. About 10-20% of these patients develop symptomatic spinal cord compression, and this number is projected to increase [6]. Therefore, it is very urgent to develop a new therapeutic strategy to manage pain and neurologic deficit of spinal metastases.

Clinical treatment options available for spinal metastases include medical therapy, radiation, and surgery [7]. Surgical resection appears to be the most effective therapy strategy [8]. The major goals of the operation are to relieve pain and neurologic symptoms, improve neurologic function, stabilize the spine, restrain local tumor recurrence, and prolong survival time [9,10]. The indications for surgical treatment include intractable pain, severe neural compression, obvious spinal instability and deformity, and ongoing radiation failure. However, there are substantial potential complications, including recurrence of primary malignancy caused by incomplete resection, which may be due to uncertain tumor margin, massive blood loss, cerebrospinal fluid fistulas, and new neurologic compromise [11]. Thus, it is essential to develop a complementary strategy to eliminate or alleviate these potential complications. The main indications include mechanical instability and high spinal cord compression. Surgery can significantly improve the quality of life and functional status of appropriate patients.

Surgical trends include minimally invasive surgery, emphasizing durable local control and spinal stability [12]. Recently, minimally invasive techniques such as RFA have received increasing attention due to their superiority in treating painful bone lesions [13,14]. With a sufficiently high focal temperature, RFA can destroy tumor tissue and exhibits a promising effect for pain palliation of bone metastasis patients [15,16]. Moreover, RFA combined with cementoplasty has been proved to be a safe and powerful technique for metastatic pain relief. The conditions of spinal metastases patients were improved and major goals of treatment were achieved, including pain management, as well as reduction of complications and tumors recurrence [17,18].

For patients with spinal metastases, it is extremely difficult to achieve a balance between complete tumor clearance and preserving spinal stability. Radical ventral tumor resection was found to be effective only for solitary metastases patients with a favorable long-term prognosis [19]. Multi-level spondylectomy can achieve complete tumor clearance, but at the cost of high risk of spinal instability and neurologic deterioration, which may result in poor long-term oncological outcomes [20]. Tomita et al [21] originally proposed that total en-bloc spondylectomy (TES) to achieve oncological complete tumor resection was generally not recommended for multiple spinal metastatic lesions. In this case, radiotherapy was considered as the primary treatment for multiple spinal metastases in the absence of an acute neurologic deficit [1]. In fact, palliative surgery (decompression) is often performed for multiple spinal metastases to alleviate symptom [22].

Surgical resection and RFA have their own merits in management of spinal metastases. Therefore, this retrospective study was conducted at a single center and aimed to evaluate operative and postoperative outcomes in patients with spinal metastases using vertebrectomy and combined vertebrectomy and RFA.

Material and Methods

Study Patients

A total of 49 spinal metastases patients were identified. Written informed consent was obtained from each patient. Approval of the hospital and institutional review board was obtained before acquiring and analyzing patients’ information from our institutional database. The participants were recruited and received treatment according their own wishes during April 2009 and March 2016. Data were collected, including demographics information, preoperative investigations, operation details, and postoperative evaluations. The control group consisted of 26 patients (12 males and 14 females) who underwent vertebrectomy alone. The combination group consisted of 23 patients (12 males and 11 females) who underwent combined vertebrectomy and RFA. Each patient was diagnosed with 1 kind of primary malignancy and metastatic osseous disease. All the patients had a pain problem that was considered to be partially or totally refractory to analgesic medications. Moreover, patients were required to have neurologic impairment due to metastatic epidural spinal cord compression (MESCC). The inclusion criteria were adult patients whose survival was expected to be more than 3 months, with a diagnosis of spinal metastatic tumors, and a vertebral lesion generating spinal compression symptoms or pain could be accurately defined. Patients with severe cardiopulmonary...
dysfunction or cerebrovascular disease who could not tolerate anesthesia or surgery were excluded.

**Pre-Treatment Evaluation**

Before undergoing treatment, the pain level of all the patients was strictly evaluated by VAS, which contains a 11-point scale ranging from 0 (no pain) to 10 (the most severe pain), as previously described by the Brief Pain Inventory [17]. The Frankel scale was used for assessment of neurological symptoms [2]. In addition, all patients had detailed cross-sectional imaging by either CT or MRI.

**Surgical Procedure**

For the combination group, vertebrectomy and RFA were sequentially performed via posterior approaches, which had 2 steps for a single operation in the same sitting position. RFA was first performed for the normal vertebrae and then the involved vertebrae were treated guided by preoperative radiographic findings. To expose vertebrae involvement under direct visualization, the surgical approach was posterior midline exposure under local infiltration anesthesia with 0.25~0.5% lidocaine. The success rate was 100% (53 of 53 treatments) in 13 patients. According to preoperative radiographic findings (including X-rays, CT, and MRI), RFA was first administered into the exposed normal vertebrae. For the vertebrae involved, an 11G or 13G bone puncture needle was then introduced into a Rita UniBlate unipolar needle. This step was aimed to create the desired radius of ablation based on tumor size through modulating the unipolar needle by protuberating 1.0 cm~2.0 cm. Radiofrequency temperature was maintained at 70°C to 80°C and 1 application of 10-min ablation was utilized. The whole process was monitored during RFA, and the location of the unipolar needle was quickly modified if the patient had severe pain or chest distress. After RFA was accomplished, the surgical region was temporarily closed.

In the next step, vertebrectomy was performed under general anesthesia. After extraskeletal soft tissue tumor mass was removed, the vertebral elements were resected by posterolateral approach. The anterolateral vertebral body was then exposed and the tumor located in the vertebral body was removed. Segmental pedicle screw fixation was also performed as surgical fixation for the spinal column. The collapsed spinal column was repaired and reconstructed using an artificial vertebral body in the circumstance that more than 2/3 of the vertebral body was destroyed. In addition, vertebral augmentation was created by injecting bone cement, and vertebroplasty was also performed in several segmental jumping lesions.

**Post-Treatment Follow-Up**

Assessment of pain (VAS score) was carried out at 1 month and 6 months after procedures. Neurologic recovery was assessed by the Frankel scale. Routine X-rays, contrast-enhanced CT, and MRI were performed to confirm ablation by visualizing necrosis between the soft tissue and the bone, and to identify possible complications. Local recurrence was ascertained by histological evidence or radiographic imaging. The recurrence period was calculated as the time from treatment to appearance of recurrence evidence.

**Statistical Analysis**

Data are presented as mean±SD. The Frankel scale and local recurrence rate between the 2 groups were calculated using Pearson chi-square tests. Statistical analyses were performed using SPSS 16.0 version software (SPSS, Inc., Chicago, IL, USA), and P value <0.05 was considered to be statistically significant. All reported P values are two-sided.

**Results**

**Basic Features of the Study Subjects**

The mean age of the recruited patients was 62.35±8.02 years for the control group and 63.26±7.70 years for the combination group. In the control group, the primary malignances included 7 lung cancers, 4 breast cancers, 5 prostate cancers, 6 renal cancers, 3 thyroid cancer, and 1 unknown primary malignancy. There were 60 vertebral involvements including 27 thoracic spine, 30 lumbar spine, and 3 sacrum spine. In the combination group, the primary malignances included 6 lung cancers, 4 breast cancers, 2 prostate cancers, 6 renal cancers, and 5 thyroid cancers. There were 53 vertebral involvements, including 25 thoracic spine, 27 lumbar spine, and 1 sacrum spine. Patients with spinal metastases were evaluated by Tomita score. In the control group, 6 patients scored 4, 5 patients scored 5, 7 patients scored 6, and 8 patients scored 7. In the combination group, 5 patients scored 4, 5 patients scored 5, 6 patients scored 6, and 7 patients scored 7. The 2 groups were similar in characteristics of primary tumors, comorbidities, Tomita score, and preoperative findings such as bone pain and neurologic deficit. The average procedure time of RFA was 7.35±1.75 min.

**Comparison of Treatment Outcomes**

Combined vertebrectomy and RFA alleviated pain and improved neurological status. As shown in Figure 1, the pain scale rating was significantly reduced in both groups. In the control group, the VAS score was reduced from 7.96±1.51 before surgery to 2.17±0.71 at 6 months, indicating a 92% decrease. In the combination group, the VAS score was reduced from 7.35±1.75 before surgery to 3.00±1.00 at 6 months, indicating a 59% decrease. The improvement in pain severity was statistically significant in both groups (P <0.05). The neurological status also improved in both groups. In the control group, the Frankel score increased from 5.00±0.50 before surgery to 6.57±0.59 at 6 months, indicating an 11% improvement. In the combination group, the Frankel score increased from 5.00±0.50 before surgery to 6.57±0.59 at 6 months, indicating a 11% improvement. The improvement in neurological status was statistically significant in both groups (P <0.05). No significant complications were observed in either group, including 2 cases of transient sensory deficits and 3 cases of musculoskeletal pain.

**Conclusion**

Vertebrectomy and RFA is a feasible and effective treatment for spinal metastases. The combination of vertebrectomy and RFA can significantly alleviate pain and improve neurological status. The surgical morbidity and mortality were low, and the procedure was well tolerated by the patients. The use of RFA in combination with vertebrectomy can be considered as a safe and effective treatment for spinal metastases.
4.92±1.41 at 1 month after surgery and 2.0±1.69 at 6 months after surgery (P=0.0002, 0.016). In the combination group, the VAS score was reduced from 7.39±1.37 to 4.52±1.56 at 1 month after surgery, and 2.3±1.66 at 6 month after surgery, respectively (P=0.0007, 0.005). However, there was no statistically significant difference between the 2 groups (P=0.690, at 6 months after surgery).

In the control group, 38.5% (10/26) of patients showed improved postoperative Frankel grade, and 61.5% (16/26) of patients had no changes in Frankel grade. No patients had reduced Frankel grade. In addition, 84.6% (11/13) of patients who were Frankel C before surgery became ambulatory after surgery, changing to Frankel D grade. One patient who was nonambulatory Frankel B grade before surgery improved to Frankel D grade after surgery, and 22.2% (2/9) of patients who were Frankel D grade before surgery improved to Frankel E grade after surgery. Neurological function was improved in both groups, and there was no statistically significant difference between the 2 treatment groups (P=0.117) (Table 1).

Combined vertebrectomy and RFA improved surgical outcome. The average blood loss was 1088.7±429.9 ml per patient in the combination group, which was less compared with 1601.9±610.3 ml per patient in the control group (Figure 2, P=0.002). The operation time was shortened from 309.42±89.72 min in the control group to 207.39±88.02 min in the combination group (Figure 3, P<0.001).

Combined vertebrectomy and RFA decreased recurrence incidence and prolonged the recurrence-free period. As shown in Table 2, 19 patients (73%) in the control group developed recurrence at the end of the study, whereas 7 patients (30.4%) developed recurrence in the combination group. The 2 groups showed a statistically significant difference in recurrence rate (P=0.003). Moreover, the recurrence period in the control group was 9.84±2.93 months, whereas the mean recurrence period in the combination group was 14.00±2.24 months. The period between treatment and recurrence was significantly longer in the combination group than in the control group (Figure 4, P=0.002).

Combined vertebrectomy and RFA improved neurological function. VAS score was reduced in both groups. There was a statistically significant decrease (P=0.0002, 0.016) in the control group, while in the combination group there was a statistically more significant decrease (P=0.0007, 0.005). However, there was no statistically significant difference between the 2 groups (P=0.690, at 6 months after surgery).

Pre – pre-treatment; Post-1 – 1 month after surgery; Post-6 – 6 months after surgery. Data are presented as mean±SD. VAS – visual analog scale.

**Table 1.** Post-treatment versus pre-treatment neurologic status by Frankel scale.

| Group     | Improvement (n, %) | No change (n, %) | P-value |
|-----------|-------------------|-----------------|---------|
| Control   | 10 (38.5%)        | 16 (61.5%)      | 0.117   |
| Combination | 14 (68.2%)       | 9 (31.8%)       |         |

P values were calculated by Pearson chi-square tests.

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In the control group, 38.5% (10/26) of patients showed improved postoperative Frankel grade, and 61.5% (16/26) of patients had no changes in Frankel grade. No patients had reduced Frankel grade. In addition, 64.3% (9/14) of patients who were Frankel C before surgery became ambulatory after surgery, changing to Frankel D grade, and 8.3% (1/12) of patients who were Frankel D grade before surgery improved to Frankel E grade. In the combination group, 60.9% (14/23) of patients showed improved postoperative Frankel grade, and 39.1% (9/23) of patients had no changes in Frankel grade. No patients had reduced Frankel grade. In addition, 84.6% (11/13) of patients who were Frankel C before surgery became ambulatory after surgery, changing to Frankel D grade. One patient who was nonambulatory Frankel B grade before surgery improved to Frankel D grade after surgery, and 22.2% (2/9) of patients who were Frankel D grade before surgery improved to Frankel E grade after surgery.

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Discussion

Previous studies found that RFA combined with PVP is mainly used in the treatment of spinal metastases to alleviate pain and strengthen the stability of vertebrae, but pain relief is limited [2,13,17,18]. The present retrospective study showed that the selective use of combined vertebrectomy and RFA significantly reduced surgical time and blood loss, improved recovery of neurologic deficit, and reduced the tumor recurrence rate in patients with spinal metastases.

The management of spinal metastases has been evolving in past decade [5,24]. Surgical resection remains a standard palliative treatment [2]. However, the limited efficacy of laminectomy and its associated complications such as spinal instability increasingly give rise to a notion that surgery cannot be the primary treatment for metastatic spinal disease [25,26]. Therefore, surgical techniques, implants, and expertise have evolved, and circumferential decompression and stabilization have been developed and are becoming more widely used in managing metastatic spine disease [27,28]. RFA is a recently emerging modality which is considered to be safe, effective, and repeatable, and with low morbidity and mortality [14].

Minimally invasive targeted RFA with cement augmentation of spinal metastatic lesions is an effective treatment for patients with vertebral body metastases [29].

In this study, we compared the clinical outcomes of patients receiving vertebrectomy alone and those receiving combined vertebrectomy and RFA for treating spinal metastases. Our observations demonstrated the combined vertebrectomy and RFA is expected to be an available therapeutic modality for managing spinal metastases. Combined vertebrectomy and RFA could effectively alleviate intractable metastatic pain, improve surgical outcomes, decrease recurrence rate, and prolong the recurrence-free period.

Previous studies have reported that surgery could relieve intractable metastatic pain and improve neurologic function [22]. A recently published randomized controlled trial showed the effectiveness of surgery in improving neurologic function in patients with metastatic spinal disease [22]. Surgical resection in negative tumor margin could provide significant relief of bone pain, improve neurologic function, and increase postoperative survival for patients with solitary spinal metastases [30]. These findings are consistent with the results of the
present study (Figure 1). RFA was also reported to be effective for pain relief [31]. In the present study, 38.5% (10/26) of patients showed improved postoperative Frankel grade in the control group, and 60.9% (14/23) of patients showed improved postoperative Frankel grade in the combination group. However, combined vertebrectomy and RFA did not further enhance the effects of pain relief or improvement of neurologic function by vertebrectomy.

Massive blood loss and longer operation time may pose additional challenges to surgical resection [32]. We found that combined vertebrectomy and RFA could effectively reduce blood loss and shorten the operation time (Figures 2, 3) compared with vertebrectomy alone, which was similar to previous reports [21,33]. RFA has been proved to be highly effective in achieving coagulation necrosis in tumors [3,34], and thus reduces intratumoral microvessel density and blood concentration [15]. Accordingly, vertebrectomy is expected to minimize bleeding and shorten the operation time. During surgery, we also observed that RFA created several confluent areas of necrosis in all cases, and the subsequent tumor masses were remarkably decreased. Our study demonstrated RFA is an important complementary treatment for surgical resection, especially when there are no definite tumor margins or abundant blood supply. In those cases, resection might lead to a bleeding problem, especially for those patients with thrombocytopenia and coagulopathy.

Local recurrence can prevent recovery of neurological function and worsen long-term outcomes, affecting the prognosis of spinal metastases patients. In this novel treatment, large tumors with neurological compromise due to metastatic epidural spinal cord compression were first ablated and then removed by vertebrectomy, while single small ones without neurologic deficit were directly ablated. RFA can result in necrosis of tumor tissue and promote tumor cell death, so RFA should be able to facilitate curative vertebrectomy and prevent recurrence. Our findings suggest that combined vertebrectomy and RFA can decrease recurrence rates (Table 2) and prolong the recurrence-free interval (Figure 4).

For treating spinal metastases, we found that in some situations the combination approach may be easier. First of all, RFA under direct visualization can ablate tumors and achieve complete tumor clearance with lower risk, especially when the tumor is extremely close to an important anatomical structure such as a major vessel, nerve root, or spinal cord. Secondly, it is much safer to use RFA when mobilizing the spine, while resection may lead to bleeding problems. These findings, together with previous evidence, strongly support that RFA is an appealing complementary treatment for vertebrectomy [1,14,31].

The limitation of this study is the small sample size in a single center, and larger samples and multicenter clinical research are needed to confirm the clinical value of combined vertebrectomy and RFA. Radiofrequency ablation has been widely used to treat spinal metastases in the last 10 years, but the most suitable working parameters need to be explored, and there are some differences between different types of probes. RFA can cause coagulation necrosis and apoptosis of vertebral tumors, but the specific mechanism still needs to be further studied.

Conclusions

This study showed that the selective use of combined vertebrectomy and RFA significantly reduced surgical time and blood loss, improved recovery of neurologic deficit, and reduced the recurrence rate in patients with spinal metastases.

Statement

The present study was approved by Tianjin Medical University Cancer Institute and Hospital (Tianjin, China) and it conforms to the provisions of the Declaration of Helsinki. Written informed consent was obtained from all individuals in the present study.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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