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Review Article

ROLE OF PERCUTANEOUS VERTEBROPLASTY IN THE TREATMENT OF SPINAL METASTASIS TUMORS

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ABSTRACT

Percutaneous Vertebroplasty (PVP) is a minimally invasive image-guided procedure widely accepted as safe and effective for the treatment of pain due to vertebral fracture of different aetiology like osteoporotic, traumatic, or neoplastic. However, Percutaneous Vertebroplasty (PVP) can be performed to the treatment of the thoracic, cervical, and lumbar spine. It is technically challenging for the treatment of the cervical spine due to complex anatomy. Hence Percutaneous Vertebroplasty (PVP) is an alternative technique for treating a vertebral fracture of the thoracic and lumbar spine. In the ageing populations, the incidence rate of osteoporotic or neoplastic vertebral compression fracture(VCF) is increasing and becoming a significant health care issue; thus, Minimal invasive procedure Percutaneous Vertebroplasty (PVP) is a method of choice in the treatment of the vertebral fracture and spinal metastasis. The focus of this review study is to evaluate the complication rate and efficacy of Percutaneous Vertebroplasty (PVP) in patients with spinal tumors.

Keywords: Percutaneous Vertebroplasty (PVP), Spinal tumors, vertebral compression fracture(VCF)

BACKGROUND

Spinal metastasis is normal in cancer patients. The spine, after the lung and liver, is the third most common site for metastasizing cancer cells.(1) That represents 70% of all osseous metastases. Approximately 5–30% of patients with systemic cancer may have spinal metastasis; some studies have reported that 30–70% of primary tumor patients have an auto-metastatic spinal disease. Spinal metastases are significantly more common in males than in females and adults 40–65 years of age than in others. Fortunately, about 10% of these patients are symptomatic, and around 94–98% of those patients with epidural and vertebral involvement are current. The extramedullary and intramedullary intradural seed of systemic cancer is rare, accounting for 5–6% and 0.5–1% of spinal metastases, respectively.(2–4) Spread from primary tumors is mainly via the arterial pathway. The direct invasion may also occur via the intervertebral foramina.(5) In addition to the mass effect, an epidural mass may distort the cord resulting in demyelination or axonal destruction. Vascular dysfunction results in vein obstruction and vasogenic oedema of the spinal cord, resulting in venous infarction and haemorrhage. About 70% of symptomatic lesions occur in the thoracic region of the spine, particularly at the T4-T7 stage. Among the remainder, there is 20% in the lumbar region and 10% in the cervical spine. More than 50% of patients with spinal metastasis is involved in many stages. Approximately 10-38% of patients have multiple non-contiguous segments involved. Primary sources of metastatic spinal disease include the following; Lung - 31%, Breast-24%, GI tract - 9%, Prostate - 8%, Melanoma - 4%, Unknown - 2%, Kidney - 1%, Others including multiple myeloma - 13%.(6,7)

In 1984 the first percutaneous vertebroplasty was performed by Galibert and Deramend, interventional neurologists in Amiens, France. These French doctors inserted bone cement polymethylmethacrylate (PMMA) into the vertebra of C2 compromised by painful vertebral hemangioma and chronic pain relieved in the patient. PMMA was later inserted into the vertebral body of vertebrae fracture by osteoporosis through a similar percutaneous procedure, assisted by fluoroscopic guidance. Vertebroplasty (VP), first described in 1987 by Galibert and colleagues, has become a commonly used alternative remedy to conventional therapy for symptomatic refractory VFs.(8–10) VP is a minimally invasive image-guided procedure that involves the application of bone cement into a fracture of the vertebral body in an attempt to relieve pain and fracture stabilization. Polymethylmethacrylate (PMMA) remains the most commonly used Cement drug. Kyphoplasty is a similar technique using an inflatable balloon clamp to which the fracture and build space to enable potentially safer injection of cement into the broken body.(11–13) Percutaneous vertebroplasty is a minimally invasive technique in which a medical-grade cement is injected percutaneously into the fractured vertebra or vertebral lesion from the posterior aspect that passes through the pedicle into vertebral body with guidance of Digital Subtraction Angiography(DSA).(13–15) The thermal reaction produced by the cement on the setting, bloc the nerve endings that supply the fractured vertebra and thus provides immediate pain relief. The cement by itself offers stability by preventing further compression of the fractured vertebra on loading. This strengthens the vertebral bodies and improving spinal stability, allowing most patients to discontinue or significantly decrease analgesics and resume regular activity. Therefore, PVP has been in operation for almost 20 years. Since this time, its use in the treatment of spinal metastases has been increasingly expanded across the world and its beneficial effects have been widely recognized by clinicians and patients.(16–18)

Across the US there are about 180,000 new cases of metastatic vertebral column involvement worldwide, with up to one-third of all cancer patients experiencing spinal column metastasis. Hence, increasing the incidence of spinal metastasis is widespread and requires vast quantities of money to provide vital health services to these patients. Surgeons and neurosurgical specialize in recent trends in the treatment of spinal metastases.(19,20)

A new field called minimally invasive spinal surgery (MISS) has developed and is expanding rapidly to decrease surgical morbidity and reduce recovery time. MISS refers to several procedures whose primary purpose is to minimize damage to the underlying anatomical structures during the approach to the surgical site. These new techniques have transformed many of the traditional spinal procedures, including microdiscectomy, interbody fusion, and pedicle screw/rod fixation. MISS proponents cite shorter operating times, less blood loss, less postoperative pain, reduced substance usage, shorter hospital stays and lower costs.(21,22)

Role of radiation therapy in spinal metastases:

Since surgery is only considered in selected cases, conventional external beam radiotherapy (CER) remains the mainstay treatment modality for spinal metastases. A new discovery is used in the field of radiation, usually one or two upper vertebral segments and 2 lower segments. The degree affected to make up for internal Vertebral movement.(23,24) This approach reveals healthy tissue for radiation, like fragile spinal cord. The radiation dose is fractionated to allow recovery of normal tissue which improves tolerance. Spinal stereotactic radiosurgery (SRS) is a bit more recently established type of radiation therapy that offers a high dose of tumor radiation, thus reducing Sum administered to adjacent healthy tissues. High resolution stereotactic describe the goal Imaging, which involves rigid dorsal immobilization Give an effective and conformal dosage using frame or frameless techniques focused on external removable immobilizers or Signs Fiduciary. Nevertheless, still, the efficiency, the safety, precise indications, and long-term assessment of disease regulation of the consequences of SRS remain unresolved.(25,26)

PVP combined with ablation by microwave (PVP combined with MWA):

Microwave ablation applies electromagnetic microwaves via an antenna to the target tissue, causing ionic molecules to agitate and frictional heat. The target tissue subsequently gets coagulative necrosis. Microwave ablation is particularly effective against lesions in the osteoblasts. It does have some disadvantages, however, including possible permanent damage to the surrounding tissue and structures due to overheating. Strict regulation of temperature during metastatic ablation of the tumor is therefore crucial to avoid spinal injury. Despite this, many research suggests that ablation by microwaves is an effective method of treating spinal metastases.(27)

During the PVP combined with MWA treatment procedure we should perform microwave ablations of the tumor. Microwave ablation of tumor cells is achieved primarily with Electromagnetic methods which result in the destruction of tumors using apparatus with frequencies between 900 and 2500 MHz. Electromagnetic microwaves heat matter causing friction by agitating water molecules in the affected and surrounding tissue. And heat that induces cell death through necrosis coagulation. After then only cement augmentation filling with PMMA process was started. (28)

Pusceddu et al recorded MWA of 37 in his retrospective study with spinal metastases (35 patients) which included 12 patients with spinal lesions. All patients have had local tumor control and significant pain palliative care, 1 week, 1 month, and 6 months after ablation (and 1 year after ablation in patients who survived at the time). They also reported improved ability to walk, and no significant complications.(29)

In 69 patients with spinal metastases M.A Khan et al. conducted a retrospective study of PVP and MWA. Study shows 8 patients were found to have died within 6 months of surgery; of the remaining patients, 61 out of 69 patients had 20-24 weeks of follow-up, 59 patients had no local development, and 2 cases of S1 nerve heat damage and skin burning occurred during the operation. The combination of PVP and MWA is obviously capable of providing long-lasting pain relief without significant adverse reactions.(30)

In a retrospective analysis, Kastler et al. announced effective treatment of 20 spinal metastases (17 patients) with MWA (in nine cases with vertebroplasty). They reported pain relief in 16 out of 17 patients, with significant pain reduction 1 day, 1 week, 1 month, 3 months, and 6 months following ablation without major complications. Pain relief without any other serious complications; the use of thermoelectricity during microwave bone metastasis ablation can be hypothesized. It's a feasible technique that can effectively prevent tissue damage around the tumor.(31)

Radiofrequency ablation(RFA) combined with PVP:

Radiofrequency ablation (RFA) and Percutaneous vertebroplasty are minimally invasive image-guided procedures that have demonstrated adequate pain control and bone stabilization outcomes for spinal metastatic cases include vertebral fractures, nerve root and compression of the spinal cord. Up to 10–20% of patients with compression of the spinal cord, most often due to posterior extension of tumor of the vertebral body. The primary objectives of spinal metastases therapy are therefore primarily the palliation and maintenance of neurological function.

Ping-lin yang et al. studies about Image-guided minimally invasive percutaneous treatment of spinal metastasis shows that RFA combined with vertebral augmentation was used in cases presenting destruction of the epidural soft tissue mass and accessories, and pathological vertebral fractures. RFA is a technology of coagulated necrosis that uses a radio wave (450-500 kHz) to vibrate electrodes inserted into the lesions and heat the surrounding tissue (50-100˚C). PVP can relieve pain and stabilize the fracture, prevent pathological fracture and deformity, and strengthen the spinal stability. The combination of RFA and PVP for the treatment of malignant tumors of the spine can effectively enhance the strength and hardness of the spine, while causing the death of tumor cells. In conclusion, RFA combined with PVP for the treatment of spinal metastasis is able to quickly relieve pain, kill tumor cells, increase the vertebral strength and improve the stability of the spine. RFA followed by PVP can reduce the risk of leakage of bone cement, particularly the leakage in vascular extrapyramidal or dura regions, while it can also improve the safety of PVP treatment.(32)

PVP combined with Cryoablation:

Cancer cryoablation is a treatment for the killing of cancer cells with freezing temperatures. A thin, wandlike needle (cryoprobe) is inserted through your skin and into the cancerous tumor directly during cryoablation. To freeze the tissue a gas is pumped into the cryoprobe. The tissue is then allowed to thaw. During the treatment session the freezing and thawing process is repeated several times.(33)

PVP combined with cryoablation, the compressed argon gas enters the vertebral body of the lesion through the frozen probe, and the tip of the cooled probe passes through the Joule-Thomson effect. After the ablation is completed, The PMMA was prepared during the last thaw phase, combining liquid monomer with powder cement polymer. PMMA loaded into the dedicated device was injected into the vertebral body under CT guidance.(34)

Salvatore Masala et al. retrospectively analyzed data from 23 patients with single vertebral metastasis treated with combined procedure of CVT, compared with those obtained in 23 patients treated by vertebroplasty. Pain intensity was evaluated by a visual analog scale (VAS) score administered before and 1 day, 1 week, and 1, 3, and 6 months after procedure; the results of the study showed that the VAS score and ODI score of the two groups of patients were better. There was a significant improvement before, but the VAS score and ODI score of the PVP combined with CVT group were significantly better than the single in the PVP group only, No any major complications occurred.(35)

PVP combined with minimally invasive pedicle screw fixation (PVP combined with MIPS):

In 1977, Magerl defined the technique of percutaneous pedicle screw placement. Subsequently, it was used only for temporary external fixation, and the principle was recently brought further into percutaneous internal fixation. In a few studies, percutaneous internal pedicle screw fastening is primarily defined in combination with sophisticated, personalized instruments and navigational support.(36)

Considering that PVP cannot achieve decompression of the spinal canal and a limited stable function of the spine, some scholars used PVP combined with internal fixation of the pedicle screw system. Operation implies of a minimally invasive paravertebral incision, placing pedicle screws, injecting PMMA into the target vertebral body via the PVP puncture needle and, at the same time, decompression of the spinal canal and resection of the tumor may be performed.(37,38)

Yu-tong Gu et al. retrospectively analyses 68 patients with an average age of 74.5 years (ranging from 65 to 87 years) who had thoracic or lumbar fresh osteoporotic VCFs without neurological deficiencies underwent PVP (group 1, n = 37) or PVP (group 2, n = 31) combined MIPS. The results concluded VAS decreased substantially in both groups after the surgery. The central and anterior height of the vertebral body increased significantly, and the angle of Cobb decreased significantly in both groups immediately after surgery. At the end of the follow-up period in group 2 no significant changes were observed in both the Cobb angle correction and the gains in vertebral body height obtained. However, the Cobb angle increased significantly, and the central and anterior height of the vertebral body decreased significantly 2 years after surgery compared to those immediately after group 1 surgery. Thus MIPS combined with PVP is a good choice for treating acute thoracolumbar osteoporotic VCF which can prevent secondary VCF following PVP.(39,40)

Percutaneous Kyphoplasty(PKP):

Regarding the substantial popularity of vertebroplasty, cement leakage and related harm to the spinal cord and the nerves around it The procedural drawback remained a big one. In 1994 Scholten, an orthopedic surgeon, Reiley, A Surgical Product Engineer and Inventor, And the biochemist Talmadge, seeking to reduce the extrusion and improve the position of cement; inflatable balloon inserted percutaneously Tamped beforehand on a compressed vertebral body. In 1998, Reiley performed the first kyphoplasty (KP) for osteoporotic vertebral compression fracture. PMMA cement injection to help make VP safer, Restore and rising kyphotic height Deformation.(18,41,42)

FENG CHEN et al. retrospectively studied 282 cases between April 2009 and June 2014, 282 patients with 399 vertebral lesions (thoracic vertebrae, 223; lumbar vertebrae, 176) received PKP for the treatment of spine metastasis cancer. The PKP procedures on 282 patients with spinal metastases have been successful and without serious complications. The puncture surgery's success rate was 100%. The clinical evaluation of the patients took place at 24 hours, 3 months, 6 months and 1 year postoperative. The study suggests that PKP is an efficient and minimally invasive treatment technique for patients with spinal metastases, leading to a substantial improvement in pain and patient functional status. Additionally, PKP is more manageable than vertebroplasty, and carries less risk.(43)

PVP with a combination of ^{125}I seeds implantations(Brachytherapy):

For more than 100 years, interstitial brachytherapy of radioactive particles has been used for treating tumours. In 1895 Roentgen discovered radiation of ^{125}I. In 1901, Pierre Curie was the first to suggest interstitial brachytherapy, involving the injection of radioactive sources directly into cancerous tissue. In 1903, Strebel treated tumors by injecting radium-226 through a needle into the tumour, thereby The distance from the radioactive source to the target site in brachytherapy will be less than 5 cm, which is different from the optimal distance for traditional external beam radiation. High doses of radiation are emitted within the target area due to the particular physical properties of radionuclides. However, the dosage is reduced rapidly in the natural tissues surrounding the tumour. Secondary brachytherapy may, therefore, destroy tumor cells, protect normal tissues, and complications establishing a precedent for tumor treatment by interstitial implantation of radioactive sources.(12)

PVPI is the process where bone cement PMMA pushed into the diseased vertebral body before the high pressure is inserted into the pathological vertebra. Radioactive ^{125}I particles are implanted in the body.

Yang et al. reported for the first time in 2005 that 1 case of PVPI treatment for lung cancer with thoracic 5 vertebral metastases and spinal cord compression. In the case of the patient, the patient implanted a total of 9 ^{125}I particles, and a total of 3.0mL of cement was injected; a good spine was restored after surgery. The column function relieved the symptoms of spinal cord compression and achieved satisfactory clinical results.(44)

Yang z et al. performed retrospective study of total 80 patients of metastatic spinal tumors, with a total of 126 vertebral lesions in between July 2004 to July 2006. They randomly divided into the two groups to receive PVP alone or PVP combined with interstitial implantation of ^{125}I seeds. The two treatment groups were identical in terms of all baseline data before treatment, including age, visual analogue pain scale(VAS), karnofsky performance score(KPS), distribution of primary tumors in various organs< numbers of spinal lesions, and metastatic foci (all values of p>0.005), indicating good randomization. Both groups received conventional chemotherapy after the operation according to their primary diseases.

Therefore, he concluded PVP is a simple operation causing only small wounds and few complications. It can effectively alleviate pain from metastatic spinal tumors in patients, improve quality of life, and reduce the incidence rate of paraplegia. Clinical outcomes can be enhanced by the combination of interstitial implantation of ^{125}I seeds.(45)

Yang et al. Performed animal model research study of total 14 healthy adult female Banna mini_pigs and published an article in 2013. Three groups were randomly divided, group A received the PVP with ^{125}I implantation(n=6), group B received the ^{125}I implantation alone(n=6), group C was kept as age-matched normal control(n=2).

Therefore, he concluded that PVP with ^{125}I brachytherapy is an effective method to treat spinal metastasis tumor, and that the Banna mini-pig can be a suitable model to investigate the mechanism of brachytherapy complications.(46)

Lin xie et al., reviewed the status and prospects of percutaneous vertebroplasty combined with ^{125}I seed implantation for the treatment of spinal metastases in 2015. As PVPI being minimally invasive therapy is very safe, reliable, effective. PVP and ^{125}I seed implantation enhance each other's effects and represent a novel, broadly applicable method of treating spinal metastases.(12)

DISCUSSION

Bone is the third most commonly seen metastatic site. Spinal metastases are becoming more prevalent due to increased cancer incidence and improved cancer survival. The back half of the body of the vertebrae is generally involved first and most often.(47) The activating factor of osteoclasts produced by tumor cells is responsible for bone resorption and bone degradation. Bone loss may lead to reduced stability of the spinal cord, causing pain, pathological fracturing, a fracturing of the compression of the vertebral body, scoliosis, and syndromes of nerve or spinal compression.(48)

In contrast, the aims of spinal metastasis therapy are pain management and spinal stabilization reconstruction. The medical treatment of bone metastases, including surgical methods and radiation therapy, and targeted medical therapy, has made substantial progress. Such methods, however, are at best just palliative and do not boost overall survival for patients. Spine metastatic disease occurs in several different forms. Pain is present in almost all situations and can be severe enough to avoid everyday tasks such as walking. Remains challenging the challenges of finding more efficient and accurate molecular target therapy to prevent and cure bone metastases and to improve the quality of life in these patients. PVP is a well-known minimally invasive surgical technique effective in relieving pain, in comparison with open surgery for the treatment of spinal osteoporotic, malignant, and traumatic spinal fractures. PVP also prevents vertebral collapse and contributes to increasing spinal stability. However, it has limited anti-tumor effects.(48–51)

The present research found that in patients with multiple spinal metastases, PVP has rapidly relieved thoracolumbar and back pain. The reasons for this may be as follows:

I) The Polymethylmethacrylate (PMMA) stable and supportive functions on the vertebral body.

The PMMA injected into the vertebrae solidifies into clusters in a short time, inhibiting the reduction of the supporting force induced by vertebral damage and repairing the micro- injury of the vertebral bodies involved, thus minimizing the pressure on the nerve roots and the vertebral sinus nerve due to the lack of spine stability.(52,53)

(ii) The thermogenic effect during PMMA polymerization. PMMA polymerization raises the vertebral body's local temperature, reaching 52 to 93 ^{0}C, leading to degeneration, necrosis, and loss of feeling in the vertebral body's pain nerve endings. The heat also effectively inactivates the tumor cells and reduces the inflammation and pain mediator production. The heat also stops cancer cells from developing and reduces their compression at the end of the nerve.(7)

iii) PMMA toxicity to the monomer. PMMA produces monomers with toxic side effects in the body, which cause peripheral nerve endings and necrosis of the tumor cells.

The frequency of PVP operation complications was higher in tumor patients (5% -10%) than in patients with osteoporotic fractures (1% -3%) or hemangiomas (2% -5%). There are two major risks of PVP: one is the extra vertebral leakage of cement into the spinal canal or paravertebral venous plexus, which may result in spinal compression or pulmonary embolism; the other is the possibility of adjacent or distant vertebral bodies re-fracturing.(17,54)

Anselmetti et al. performed PVP in 60 patients to assess the difference between the high viscosity cement group and normal low-viscosity cement group in cement leakage. The findings showed that the reduction of venous leakage from high viscosity cement was very significant ($p<0.0001$), while the intervertebral disc-related result was not significant ($p=0.14$). A retrospective analysis assessing risk factors for cement leakage after PVP found that prior clinical history was correlated with reduced cement leakage, and that vertebral failure and cortical degradation of the end plate were risk factors for cortical cement leakage.(55)

Yang et al. evaluated the variation in clinical efficacy between PVP combined with the implantation of ^{125}I seeds and traditional radiotherapy. At 1 month, 6 months and 1 year after treatments, the combined group's VAS score was significantly lower than that of the radiotherapy group ($p<0.01$), and the combined group's life quality score was also significantly lower than that of the radiotherapy group ($p<0.01$).(56)

Another research, published in 2009 by Yang et al., compared differences in clinical outcomes between PVP alone and PVP combined with implantation of ^{125}I seeds. They noticed that the combined group's VAS scores (2.26 vs. 5.41, P=0.028) and the combined group's KPS scores (92.5 vs. 87.7, P=0.009) were considered superior to the PVP community alone. Therefore, it can be expected that PVP combined with the implantation of ^{125}I seeds can improve the effectiveness of each other and can in the near future become a safe and efficient strategy for the treatment of spinal metastases.(50)

Retrospectively, H sun et al. assess the efficacy of PVP in the treatment of metastatic spinal tumors in a total of 120 patients diagnosed with spinal metastasis who have had PVP. His research shows that variations between pre- and postoperative VAS pain levels at any point in time when tests were taken (P\ 0.001) are substantially different. No statistical difference was found at any point in group analyzes about the VAS pain scores (P [0.05). The variations between pre- and postoperative KPS scores are substantially different at any point in time (P\0.001). At any point in time between group analyzes (P) [KPS scores in group A were not statistically different from those in groups B, C, and D (P [0.05).(57)

Sergiy V. Kushchayev et al. concludes that modifications based on VP and vertebroplasty have huge potential for drastic reduction of waiting times, health care costs, complication rates, time to heal and improve patient satisfaction, both by replacing alternative surgical procedures and by providing disease treatments had previously been inoperable. These, then, are Vertebroplasty-based imaging-guided spine techniques continue to develop and remain an intellectually active area of research.(58)

CONCLUSION

In this review concluded that PVP is a safe and effective procedure effectively relieves the pain caused by osteolytic vertebral metastases, increases vertebral strength, and improves spinal stability in patients with metastatic spinal tumor without epidural involvement. Moreover, PVP can significantly prevent the invasion of spinal tumors and improve the patient's quality of life. This innovative technology for micro-spinal surgery is likely to become one of the primary means of palliative treatment for multiple Spinal metastases. Since current studies have shown contradictory outcomes, well-designed randomized clinical trials are needed to determine the relative strengths and limitations of this technique. Further work will concentrate on reducing the complications and promising long-term efficacy and improved safety.

Conflict of interest: None

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