

Spine metastases: are minimally invasive surgical techniques living up to the hype?

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Practice points

- Open surgery is efficient but associated with a high morbidity rate.
- Minimally invasive surgical techniques have been developed to overcome these drawbacks while providing the same benefits.
- Osteolysis-induced instability must be assessed.
- A strict evaluation is required to propose the most appropriate technique, tailored to each patient.
- Due to the multiplicity of clinical and radiological presentations a multidisciplinary approach is needed.
- These techniques are not competitive and can be associated with each other.

SUMMARY Surgery is still considered the mainstay treatment of spine metastases. However, conventional surgery is associated with a high complication rate that may delay the initiation of adjuvant therapies and make some patients not eligible. Minimally invasive surgical techniques have been developed to overcome these drawbacks while providing the same benefits than standard open surgery. In recent years, there has been a flourishing enthusiasm demonstrating the advantages of these various techniques. Although, it is clear that these techniques have greatly improved the treatment of spine metastases, each has its own limitations. In this report, we list the main minimally invasive surgical techniques emphasizing their advantages and drawbacks.

Bone is the third most common site of metastases following lung and liver [1]. Primary tumors most likely to metastasize to the bone are breast, lung and prostate, reflecting both their high prevalence and their predilection to bone [2]. Of the various bones, the spine is the most commonly affected site and we estimate that spine metastases occur in 30–50% of cancer patients [3]. Spine metastases are a serious concern, as they can cause various complications such as intractable pain, spinal fractures and spinal cord compression that can severely affect the patients' ambulation and quality of life. For many decades, radiation therapy has been the mainstay of treatment of spine metastases [4], until a randomized controlled trial has demonstrated the benefit of surgery regarding pain control and maintenance of patients' autonomy [5]. Indeed, both developments of surgical techniques and spinal instrumentations allowed surgeons to ensure wide spinal cord decompression and solid constructs. However, open surgery presents many drawbacks limiting its use to patients in good

KEYWORDS

- cryoplasty • kyphoplasty
- minimally invasive
- percutaneous stabilization
- radiofrequency ablation
- spine metastases
- stereotactic radiosurgery

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general condition, with a life expectancy greater than 6 months and for whom a wide resection of the metastasis is desirable [6]. In recent years, there has been an enthusiastic development of minimally invasive techniques, enabling to offer patients a large panel of therapeutic options with a limited morbidity [7,8]. Innovations in radiation therapy and especially in stereotactic radiosurgery (SRS) have also considerably advanced the treatment of spine metastasis [9]. The multiplicity of clinical and radiological presentations explains why there is no consensus regarding ideal treatment of spine metastases. Then, their management requires a truly multidisciplinary approach involving oncologists, radiation oncologists, interventional radiologists and spine surgeons. Each technique has advantages and risks that must be well known. Thus, the choice of treatment requires a precise clinical and radiological evaluation. These techniques are not competing and within a multidisciplinary team, the goals of treatment should be clearly defined to offer each patient the most appropriate treatment.

Indications

The therapeutic indication is closely dependent on the patients' life expectancy. Many scoring systems have been developed in order to better assess the life expectancy of patients with spine metastases from solid cancer [10–12]. The Tokuhashi score [11], which is the most widely used, takes into consideration six parameters such neurological status, primary cancer, cancer spread and patient general condition (total score 0–15). This score aims to guide the choice of therapy by assessing the life expectancy, which is a determining criteria. When the total score is inferior to 8, the life expectancy is likely to be less than 6 months and a palliative approach is preferable. By contrast, more aggressive treatment may be considered for a score higher than 12/15, because the estimated survival is greater than 1 year. In such rare cases, a spine metastasis may require an excisional surgery. The ideal indication is a patient in a good general condition, with a perfectly controlled primitive cancer, who suffers from a single spine metastasis. These rare situations must be detected in order to offer the patient the treatment that may improve his life expectancy. These rare cases are candidate to open surgery even if asymptomatic, as none of the minimally invasive techniques has demonstrated its validity in this particular indication. However, in the vast majority of

cases, the management of vertebral metastases remains purely palliative. Nonthreatening and asymptomatic metastases should benefit from a medical treatment followed by close supervision. The medical treatment is a combination of anticancer therapy (if needed) and bone-targeted therapy like bisphosphonates and denosumab that inhibit osteoclast-mediated bone resorption. These treatments have demonstrated their efficiency in preventing skeletal-related events in patients with advanced cancer metastatic to bone [13]. Thus only symptomatic and/or instable metastases should be considered for treatment.

Clinical & radiological evaluation

• Pain

Pain is the most commonly reported symptom, occurring in up to 80% of patients affected by spine metastasis [14]. Pain must be quantitatively measured using the visual analog scale and especially characterized. Indeed, there are various causes to pain, which have different semiological characteristics, and thus different treatments. First, pain can be directly due to the tumor mass that causes local inflammatory reaction, periosteal stretching and epidural venous plexus distension. Pain is constant, localized to the affected level and usually increased with the palpation of the concerned spinous process. Note that radiation therapy is well known to be particularly effective in this kind of pain. Second, radicular pain is reported in nearly 50% of the cases [15]. It is due to the compression of the exiting nerve root by invasion of the foramina at the affected level. For radiosensitive tumors, radiotherapy can have good efficacy by reducing the tumor mass. However, as the effect is delayed, surgical decompression is preferable in case of intractable pain. Finally, pain can be directly related to the bone destruction. This pain is typically mechanical, as increased by the upright posture and relieved by rest. Such pain must be detected, as it may indicate a threat to the spinal stability. Radiation therapy has little effect and may even worsen the situation by increasing the fracture risk [16].

• Neurological function

Spinal cord dysfunction affects 35–65% of patients with spine metastasis [4,14]. This dreaded complication must be detected as early as possible to allow prompt treatment in order to obtain good functional outcome [17]. The main prognostic factor is the patients' ability to walk before treatment [17]. If the patient is not ambulatory

before treatment, the neurologic recovery rate is poor. When neurological deficit is complete, it is most often irreversible. The dynamic and duration of symptoms must also be taken into account. Thus, prompt surgical decompression remains the treatment of choice when neurological deficit evolves rapidly, as this treatment must be rapidly effective. In the other hand, other therapeutic options such SRS may be discussed when the deficit is slowly evolving.

• **Instability assessment**

Until recently, there was no valuable scoring system and assessment of instability was largely subjective. The Spine Oncology Study Group introduced the Spinal Neoplastic Instability Score to fill this gap (Table 1) [18]. This score is defined as the sum of 6 clinical and radiological criteria easily and quickly measurable. This score has recently demonstrated its reliability [19]. Vertebral involvement associated with a high Spinal Neoplastic Instability Score exposes to the risk of intractable pain and deformity. In addition, a collapse of the vertebral body can cause sudden and irreversible damage of the neurological structures. A brace can limit the mechanical stress but has the drawbacks to alter the autonomy of patients and to relieve pain insufficiently. Surgical stabilization must be discussed systematically in such cases.

Minimally invasive techniques: advantages & limitations

All reported minimally invasive techniques have been recently introduced for the treatment of thoracolumbar spine metastasis to limit iatrogenic effects. The rationale behind this strategy is that it balances the need to stabilize the spine and/or decompress the neural structures while avoiding the morbidity associated with open procedures. Indeed, life expectancy of these patients is limited, and the treatment must improve or maintain their quality of life during the remaining time. The other advantage common to all these techniques is that they allow the rapid initiation of adjuvant therapies. Note that these techniques are not competitive and can be associated with each other when needed.

• **Vertebroplasty/kyphoplasty**

Currently, vertebroplasty and kyphoplasty are increasingly popular percutaneous techniques used for the treatment of symptomatic spine metastasis. Both procedures involve percutaneous

injection polymethyl methacrylate bone cement into the affected vertebra. Vertebroplasty involves direct injection of the polymethyl methacrylate cement into the vertebral body under fluoroscopic guidance. It provides strengthening of the vertebral body for treatment or prevention of fracture (Figure 1). Pain receptors are also destroyed by the exothermic reaction of the cement. Kyphoplasty is indicated in case of associated vertebral body collapse. The pedicles are cannulated under fluoroscopic control, using the same technique. Balloons are introduced and inflated to slightly reduce the collapse. Once the reduction achieved, the balloons are deflated and the cement is introduced progressively. Moreover, by creating a cavity, the cement is introduced without resistance, which reduces the risk of cement leakage. However, these techniques are not without risk. Cement leakage has been shown to occur in between 10 and 70% of cases on radiograph, and to reach 93% of cases when CT scan is routinely used after the procedure [20]. While most cases are reported to be asymptomatic, cement leakage into the vertebral canal can induce mechanical compression and exothermic reactions involving nerve structures. Symptomatic side effects occur in up to 10% of the cases [20]. The limitations of these techniques must be known and respected in order to avoid these dreaded complications. Symptomatic spinal cord compression and overt instability are two major contraindications for both vertebroplasty and kyphoplasty. Other situations must be considered to be more technical difficulties than actual contraindications. Some studies have demonstrated that these techniques could be performed safely in trained hands, even with a rupture of the posterior cortex, an epidural involvement or in the upper thoracic region [21,22]. Respecting these limitations, many series have reported excellent results with low morbidity [23,24]. A randomized controlled trial demonstrated that kyphoplasty was superior to conservative management for treatment of painful vertebral body fractures in patients with solid cancer [25]. In this study, Kyphoplasty allowed a rapid and durable pain relief with a low morbidity rate.

• **Percutaneous stabilization**

It has been established that stabilization reduces pain and improve quality of life for such patients [26]. However, in many cases bony destruction and deformation are such that vertebroplasty cannot be performed safely. Originally aimed to treat degenerative diseases,

Table 1. Spinal neoplastic instability score.	
Parameter	Score
Location	
Junctional (C0–C2, C7–T2, T11–L1, L5–S1)	3
Mobile spine (C3–C7, L2–L4)	2
Semirigid (T3–T10)	1
Rigid (S2–S5)	0
Pain	
Continue	3
Occasional	1
None	0
Bone lesion	
Lytic	2
Mixed	1
Blastic	0
Radiographic alignment	
Subluxation/translation	4
Deformity (scoliosis, kyphosis)	2
Normal	0
Vertebral body collapse	
>50%	3
<50%	2
No collapse but >50% body involved	1
None	0
Posterolateral involvement	
Bilateral	3
Unilateral	1
None	0
Score 0–6: Stable; Score 7–12: Potentially unstable; Score 13–18: Unstable.	
Interpretation: Score <7: Stability; 8< Score <13: Moderate instability; Score ≥13: Severe instability.	

the percutaneous pedicle screwing technique has been progressively introduced for the treatment of spinal metastases. Under general anesthesia, the patient is positioned prone on a radiolucent table, allowing AP and lateral fluoroscopic control. The pedicles are identified first, and screws are then introduced under a strict fluoroscopic guidance (Figure 2). The rods are bended to the spinal curvature and introduced percutaneously. From biomechanical point of view, long segment instrumentation seems to be safer, as distraction forces are applied over the whole length of the instrumented spine [27]. By restoring the weight-bearing properties of the spinal column, the mechanical pain is often well relieved (Figure 3). Indeed, many studies have reported very good clinical results and a low complication rate. However, this technique has some limitations. First, although the safety of percutaneous screw placement has been largely demonstrated in the literature [26,27], the visualization of the pedicles on fluoroscopic control can

be altered by the lysis of the pedicle, in case of metastatic spread. Navigation systems can be very helpful to overcome this limit. Second, as long segment instrumentation is often required, immediate postoperative course are painful and require a hospital stay of 3–4 days in most cases. This transient pain is related to the muscle splitting and should be well known and taken into consideration during the decision making. Finally, note that this technique treats the mechanical instability, but has no direct effect on the tumor. This requires an adjuvant treatment to achieve local tumor control. In practice, irradiation can be performed from the seventh postoperative day. This allows treatment of local pain related to tumor and prevents tumor growth, which could lead to compression of neurological structures.

• Percutaneous decompression

Compression of neurological structures is a frequent and severe complication that requires

prompt treatment to prevent dreaded sequelae. Radiation therapy is effective in radiosensitive tumors, but its delayed action explains that surgery is preferable when the deficit is rapidly progressive. Although, wide standard decompression remains the treatment of choice, this procedure is associated with a significant morbidity rate making some patients ineligible. Recently, some studies reported the effectiveness of minimally invasive decompression, in patients ineligible for standard procedures [28]. As percutaneous stabilization, this technique was first introduced for the treatment of degenerative diseases. The significant reduction in operative morbidity legitimized its use for the treatment of vertebral metastases. Under fluoroscopic control, dilators are progressively introduced and a 22-mm working tube is placed in front of the affected vertebrae. Under microscopic control, the neurological structures can be decompressed (Figure 4). If pain or radicular deficit, the nerve root can be decompressed easily. If necessary, it is also possible to achieve spinal cord decompression. Partial transpedicular corpectomy can be performed under microscopic control using progressive drilling. The aim of the procedure is not to remove all the tumor mass, but only to perform a debulking [28,29]. By creating a surrounding zone of decompression of few millimeters around the spinal cord, it allows good neurological recovery. In our experience, this procedure is justified by the fact that adjuvant therapy can be initiated quickly, from the seventh postoperative day. As the safety margin around the spinal cord is small, all patients should undergo postoperative radiation early, which requires a close coordination with the radiation oncologist [29].

• Radiofrequency/cryoplasty

Radiofrequency ablation (RFA) uses thermal energy to destroy tissue surrounding an electrode, resulting in coagulation necrosis of tissue from high temperatures (50–90°C). As with vertebroplasty, the thermal destruction of pain sensitive nerve fibres ceases transmission of signals, which provide a rapid pain relief. The reduction in tumor volume provides a long-lasting relief by reducing the tension to the sensitive periosteum. RFA has been first established for the treatment of metastases to the kidney and liver. In the past few years, it has been increasingly used for the treatment of osseous metastases. The first experiences reported good tumor control rate and significant pain relief. Until recently, the spine was

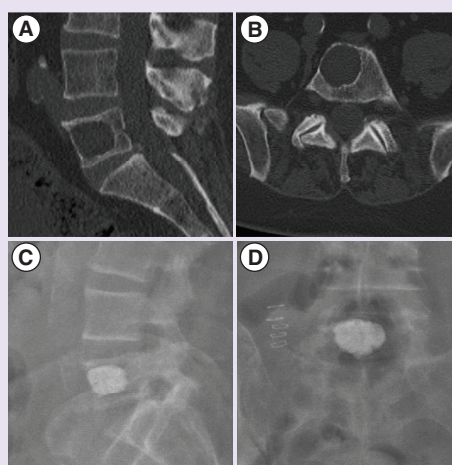


Figure 1. Percutaneous vertebroplasty. CT scan on sagittal (A) and axial view (B) revealing an osteolysis of L5 in a 50-year-old man suffering from lung cancer. Note the preservation of the cortex. Plain radiographs showing a complete filling after the vertebroplasty (C & D).

considered as a contraindication because of the exothermic reaction, which could lead to neurological damage. Technological advances have enabled the development of navigable probes, which allows increasing precision and reducing risk [30]. Metastases located in the posterior part of the vertebral body, close to the posterior wall, may also be treated by this technique.

Like RFA, percutaneous cryoplasty may provide pain relief by a cooling effect produced by the expansion of argon forced into the lesion, and subsequent generation of an ice ball. Cellular dehydration and cell death are the main mechanisms that lead to tumor destruction. This

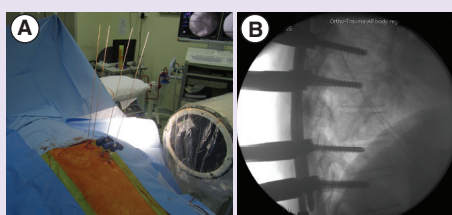


Figure 2. Percutaneous stabilization of a metastases at T10. (A) Intraoperative photograph demonstrating the placement of the wires into the pedicles. (B) Under fluoroscopic control, the screws are inserted through the wires.

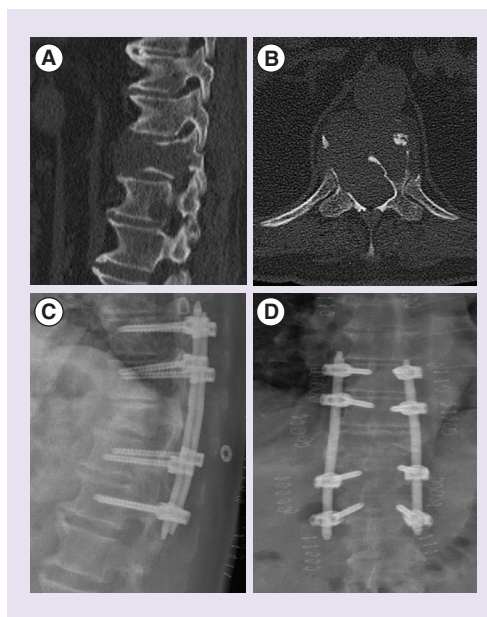


Figure 3. Percutaneous stabilization of a thoracic metastases. Metastases at T11 associated with a significant instability (A & B). Note the destruction of the posterior cortex. We performed a long segment percutaneous stabilisation. Postoperative plain radiographs on lateral (C) and antero-posterior (D) views.

technique has been employed for decades for treatment of extra-spinal bone metastases [31]. In trained teams, it demonstrated a good pain relief and efficient local tumor control obviating the need for resection surgery in the treatment of

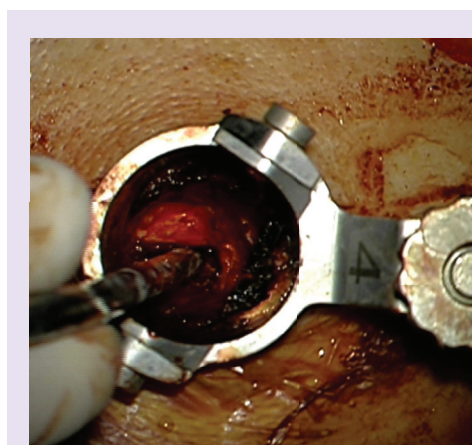


Figure 4. After placing the 22-mm working tube, we resected the lamina and the articular process under microscopic control. The dura is then widely exposed and decompressed.

primary tumors and bone metastases [32]. These two techniques, established for the control of local pain, are not indicated in case of spinal cord compression, to the extent that the proximity with the spinal cord may result in irreversible thermal damage. Moreover, these techniques should not be used alone in case of proven instability. Stabilization should be considered during the same procedure to treat mechanical pain and to prevent a further fracture (Figure 5). Although the first published series are encouraging [33], their place in the therapeutic armamentarium remains to be better defined.

• Stereotactic radiosurgery

SRS can deliver a high dose of radiation to a target volume while decreasing the amount delivered to normal tissue. SRS uses multiple conformal and focused beams to deliver high dose of radiation to the target with rapid dose fall-off to avoid surrounding healthy structures. This treatment modality presents numerous advantages over conventional radiotherapy. First, higher doses delivered in a single fraction are likely to improve efficiency. Indeed, some series report rapid and highly effective tumor control and significant pain relief [34,35]. Second, this single day outpatient treatment improves the patients' comfort and compliance, which is not inconsequential for those with a limited life expectancy. Third, SRS avoids irradiating excess bone marrow and superficial tissue to not interfere with ongoing chemotherapy. Finally, SRS can be performed for radio-resistant metastases (melanoma) and is effective for the treatment of previously irradiated lesions with an acceptable safety profile. Some recent series report a control tumor rate up to 90%, regardless of tumor histology [36]. However, surgery should be considered first in patients with rapidly progressing neurological deficit. Moreover, any spinal instability must be assessed and treated promptly, as some series have reported an increased risk of vertebral compression fracture after SRS ranging from 11 to 39% [16]. Its current limitations are the high cost and limited accessibility. Although, indications for radiosurgery are not clearly defined and will continue to evolve, this very promising technique is likely to deeply change the management of spine metastases in the coming years.

Conclusion & future perspective

As the management of spine metastases is largely palliative, the limitation of surgical morbidity is

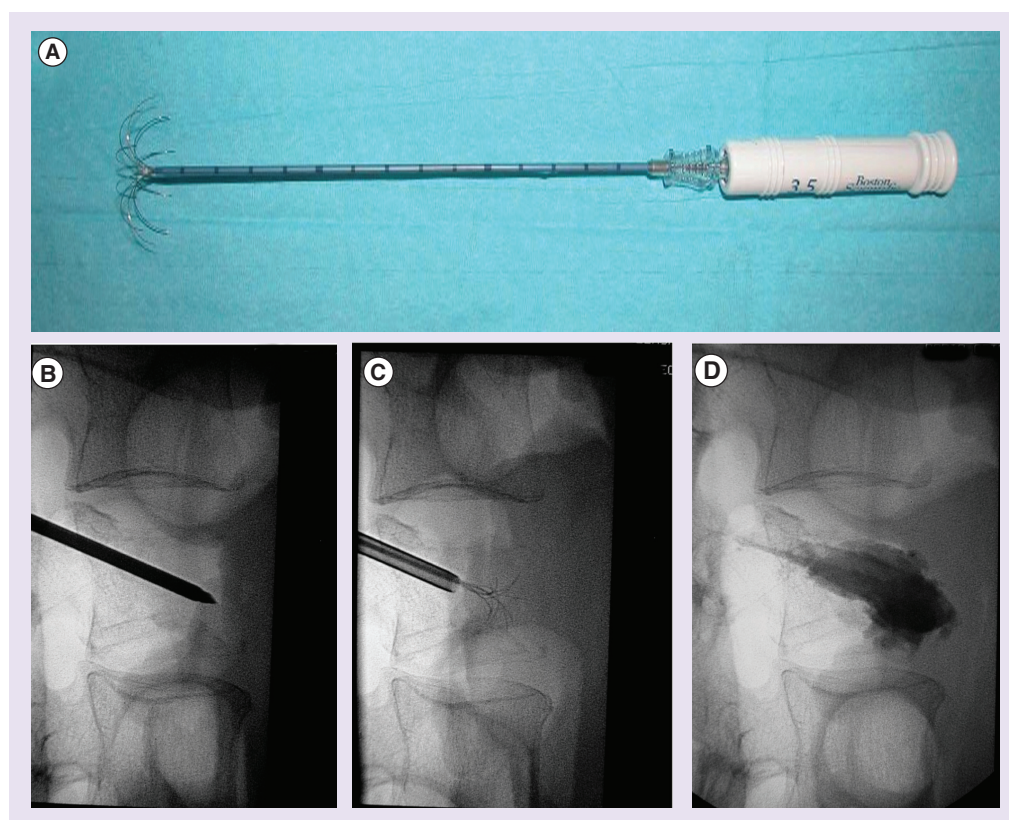


Figure 5. Combined percutaneous radiofrequency and vertebroplasty of a lumbar metastases. Radiofrequency ablation of a metastasis at L2 with an expandable probe (A). The wire is placed percutaneously into the lesion through the pedicle (B). The probe is inserted and deployed (C). A vertebroplasty is performed at the end of the procedure (D) as the spinal neoplastic instability score was superior to 8.

a major concern. Minimally invasive techniques can provide safe and effective therapeutic solutions. Early detection of spine metastases due to improved imaging techniques and advances in medical therapies are likely to reduce the incidence of vertebral fractures and spinal cord compressions. Other hand, the democratization of SRS will make this tool a first-line treatment, combined with minimally invasive stabilization techniques if needed.

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