REVIEW ARTICLE

VERTEBRAL BODY RECONSTRUCTION FOR THORACOLUMBAR SPINAL METASTASIS – A REVIEW OF TECHNIQUES

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The spine is the most common site of skeletal metastases with its involvement occurring in up to 40% of patients. Metastatic spinal involvement can cause a number of sequelae like pain, instability and neurologic compression. About 10% of patients with involvement of the vertebral column will subsequently develop neurologic compression.The metastatic spinal lesions mostly affect the vertebral body and pedicle (85%). Management of spinal metastases remains controversial. Recent reports attest to the beneficial role of surgery. The role of decompressive laminectomy without stabilization, has been questioned. The Involvement of Vertebral Body and anterior compression had led to an increasing attention to anterior decompressive procedures, reconstruction and Stabilization. We Review here the Techniques described in literature for anterior reconstruction after vertebral corpectomy.

Key Words: Spinal Metastasis, Vertebral Body, Laminectomy, Bone cement, Titanium Cages, Reconstruction.

The vertebral column is the most frequent site of bone metastasis[1,2]. Spinal metastasis occur between 5-10% of all patients with cancer during the course of disease[3.]Autopsy studies have found metastatic involvement of vertebral column in 90% of patients with prostate cancer, in 75% of patients with breast cancer and 55% of those with melanoma.

Forty five percent of patients with lung carcinoma and 30% of those with renal carcinoma are also found to have spinal metastasis on autopsy[4,5,6] .About 10% of patients with involvement of the vertebral column will subsequently develop spinal cord compression[7,8]. The metastatic spinal lesions mostly affect the vertebral body and pedicle (85%). The distribution of the metastatic lesions according to the level of vertebrae in various spinal segments is[9, 10]: thoracic spine 70%, Lumbar spine 20% and cervical spine 10%.

The treatment of spinal metastasis is primarily palliative except in rare circumstances.Treatment can consist of chemotherapy, radiotherapy, hormonal therapy and/or surgery. The current recommended indications[11] for surgery in spinal metastasis are: Radio-resistant tumor, spinal instability, progressive deformity or neurologic compromise, significant neurologic compression due to retropulsed bone or bone debris, intractable pain unresponsive to nonoperative means. Failure of radiation therapy, tolerance of spinal cord by radiation reached due to prior radiation therapy and deterioration of neurologic status during radiation therapy are few other indications.

Recently Patchell[12] reported a randomized controlled trial of 101 patients presenting with neurological compromise at a single level and randomized patients into 2 groups one receiving immediate radical decompressive surgery plus radiation therapy (RT) at 2 weeks post operatively and other group RT within 24 hrs of entry into study.

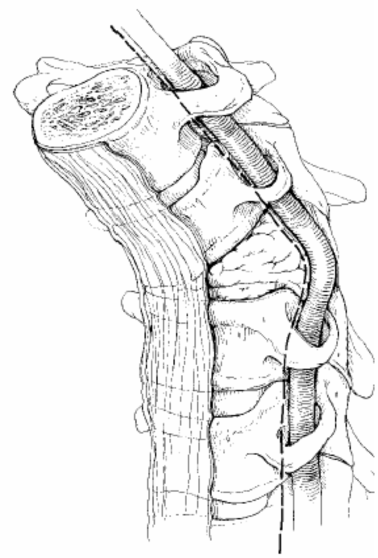


Figure 1: Replacement of the vertebral body by tumor results in collapse of the body, increasing kyphosis, and extrusion of tumor and bone fragments into the epidural space,© 1993 American Academy of Orthopaedic Surgeons. Reprinted from the *Journal of the American Academy of Orthopaedic Surgeons 1993;* 1(2): 76-86 with permission.

Both groups received 30Gy of RT at 3Gy / day for 10 days. Patients with surgically treated group were able to retain the ambulatory ability significantly longer than the RT group. Fifty six percent of the non-ambulatory patients were able to regain ambulation in the surgery group compared with 19% in RT group. Patients with Surgery plus RT group used less narcotic analgesics and had longer survival than RT alone group though both of these differences were not statistically significant.

The surgical management of metastatic spinal disease has been controversial. The initial Studies[13, 14,15] compared the results of laminectomy and adjuvant radiation therapy with radiation therapy alone in restoring the ambulatory status of the patients and found no advantage of laminectomy over radiation therapy. The vertebral body is involved in 85% of the cases (Fig 1) in spinal metastasis so doing laminectomy without stabilization removes the posterior supporting structures and causes further instability and may increase neurologic compromise and pain, though later studies using laminectomy with instrumentation had better results. Newer approaches emphasize anterior decompression and vertebral body reconstruction, combined with posterior stabilization when deemed necessary. Few recent series document neurologic improvement in approximately 75% of the patients[16,17,18,19]. Anterior surgery has multiple advantages like it allows adequate resection of the tumor mass in an expeditious fashion, removes neural compression directly and corrects deformity. Anterior decompression and reconstruction is a major surgery and is in no way proposed for every patient. Patient's physiologic reserve and life expectancy must be carefully considered before embarking upon the anterior approach.

Various Scoring systems proposed by Tokuhashi[20] and Tomita[21] help in assessing the extent of involvement, the type of treatment and the likely life expectancy of the patient. Bunger using the above two scoring systems and suggested the following algorithm[22] (Table I) for various approaches (Anterior or Posterior).

Table-1: Algorithm proposed by Bunger[22] et al regarding Surgical Strategy in Spinal Metastasis

Tokuhashi Score	Life Expectancy	Tomita Classification	Proposed Surgery
0 to 4	< 3 months	Type 1-7	Laminectomy.
5 to 8	3-6 months	Type 1-7	Posterior decompression, stabilization, and reconstruction.
9 to 12	> 6months	Type 1-3	En bloc resection with vertebrectomy and 360° reconstruction.
		Type 4-6	Intralesional vertebrectomy and 360° reconstruction.
		Type 7	Posterior decompression and stabilization.

Various techniques have been described for vertebral body reconstruction such as Polymethylmethacrylate (PMMA) used in combination with supplemental devices, bone grafts, Ceramic spacers and various kinds of metallic implants.

Structural allografts are a reliable method for vertebral reconstruction and have shown excellent compressive strength which is significantly high as compared to iliac crest autograft or rib graft. Lewandrowski [23]studied the results of fresh frozen cortical allografts used for reconstruction of vertebral body in 30 patients (19 with primary spine tumors and 11 with spinal metastasis). All patients received pre, intra and/or postoperative radiation. Curative wide resections were performed in 15 patients (11 primary tumors and 4 solitary metastasis) rest of them had intralesional resections. All 30 patients underwent anterior resections with reconstruction and instrumentation. Allografts were used from various bones like femur, tibia, humerus, clavicle, fibula and rib. Median survival was 14 months (7 months to 5yrs). Twenty eight (93%) of the 30 Patients showed incorporation of the graft on x-rays as early as 6 months after surgery in spite of radiotherapy. Fourteen patients (46%) had complications related to the procedure but there were no graft infections, fractures or collapse. Nakamura[24] used vascularized folded rib graft in for a thoracic metastasis and reported solid bony union within 4 months.

Spears[25] et al in a retrospective study observed the effect of radiation on bone grafts. There were 40 patients in the irradiated group and 15 in un-irradiated groups. The bone grafts was used in multiple places in the body with 18 bone grafts in the spine (45%) in irradiated group. There were 10 autologus bone grafts and 45 allografts in this series. Sixteen patients received preoperative radiation therapy, 11 postoperative and 13 patients received both pre and postoperative radiation. One and five year survival rates for the irradiated group was 86 and 68% whereas control group for the similar period had survival of 67 and 58%. The total irradiation dose delivered to the graft site did not significantly affected survival. Decreased survival was observed in patients receiving preoperative and combined regimen of radiation. Healing quality and healing time of the irradiated group was seen to be slower than the control group. About 70 Gy of radiation in standard fractionation is considered to be high enough for osteo-radionecrosis or fracture. Animal studies show that even lower doses would cause decreased graft survival and slow healing. Roy-Camille found no significant difference in clinical effects on graft healing or survival when radiation doses are kept below 45 Gy. Delay in delivering radiation should only be done if it does not compromise the chances of tumor eradication.

Polymethylmethacrylate (Bone Cement) has been used for vertebral body reconstruction, providing immediate stability and has satisfactory load bearing properties. Its other advantages are low cost and ease of usage. The disadvantages are chances of damage to spinal cord due to thermal injury or compression in case of spillage, dislodgement of the construct which might lead to instability or injury to the cord, risk of infection and inability to correct deformity when used alone. PMMA is more stable in compression than tension. It has been used in various modes with multiple kinds of adjuvant fixation options.

Harrington[26] described the use of the combination of the Polymethylmethacrylate (PMMA) and the Knodt rod (Fig 2). This construct very effectively resists compression and torque loads in the cervical and thoracic spine but requires adjunctive posterior stabilization devices in the lumbar spine. After complete corpectomy and decompression of the canal, a high-speed bur is used to cut a well into the intact vertebral endplates of sufficient depth and width to seat the Knodt rod and hooks. The hooks are seated firmly into the vertebrae, and the kyphotic angulation is corrected . PMMA is then packed about the rod and hooks and into the defects in the vertebral endplates. Before polymerization is complete, all excess cement is removed from outside the confines of the vertebral bodies.

Harrington[27] reported on a series consisting of 77 patients with spinal metastasis related spinal instability using the this technique and achieved satisfactory improvement of neurologic recovery. He encountered few complications like early loss of fixation (at 6 wks) in 5 patients, 3 cases of late loss of fixation and four patients had deep infection.

Perrin and McBroom from Toronto[28] devised a construct for vertebral body replacement in spinal metastasis known as Wellesley Wedge. Through anterior approach vertebral body resection and decompression was done. A 4.5mm reconstruction plate is bent in the form of U to fit into the vertebral defect and arms extending onto the vertebrae above and below. The plate was fixed above and below to the vertebrae. Following plate fixation PMMA was carefully molded into the defect keeping it away from the dural sac to prevent any cord injury. Yen[29] used this method of vertebral reconstruction in 27 patients with spinal metastasis, of these 10 had two column and 16 had 3 column disease.

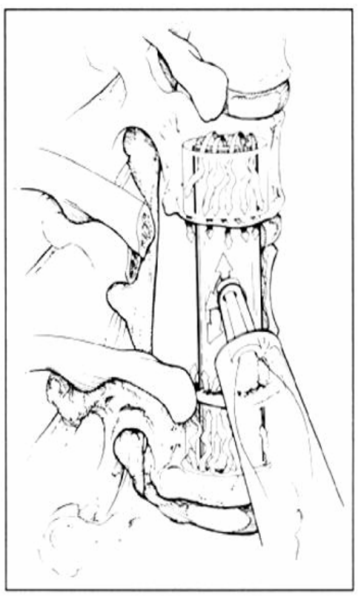
Figure 2 : Anterior stabilization with a Knodt rod and PMMA. © 1993 American Academy of Orthopaedic Surgeons. Reprinted from the *Journal of the American Academy of Orthopaedic Surgeons 1993;* 1(2):76-86, with permission.

They had 6 deaths in the 30 days postoperative period. They achieved good results regarding maintenance of spinal alignment. They had 2 failures of construct one an early failure (period not mentioned) due to poor bone quality and another due to tumor recurrence. They estimated the average cost of the construct to be 610 Canadian dollars.

Akeyson[30]used posterolateral transpedicular approach to perform a near complete spondylectomy to decompress the thecal sac, in patients with medical co-morbidities and 3 column involvement. Once the excision is completed reconstruction is done by using Steinmann pins and PMMA. Appropriate sized Steinmann pins are inserted at right angles to the end plates of the vertebrae above and below the defect. Then a Luque rectangle with cables is used to do a sublaminar fixation from 2 levels above and below the defect. Following posterior fixation PMMA in semi liquid form is poured in the defect starting from the deepest portion and moving to superficial portion with care taken to protect the spinal cord and try creating the PMMA block as a single unit. Once PMMA is hardened it is tested for stability. Patients were allowed to ambulate with Orthosis or slings. Majority of patients had full or partial pain relief after the surgery. Of 18 patients with pain and neurological deficit before surgery 10 showed improvement postoperatively. There was no 30 day mortality .The biggest complication was related to the migration of all or part of the anterior construct. It occurred in 4 patients with a range of 14 days to 7 weeks. Three of these patients presented with signs of cord compression / cauda equina. Authors have attributed this cause to improper mating of PMMA with vertebral bodies and also with insecure placement of Steinmann pins.

Errico[31] described a novel technique of reconstruction of the vertebral body using a silastic tube and PMMA applicable in lumbar and thoracic spine. After resection of the vertebral body and leaving the anterior longitudinal ligament (ALL) intact they created a central trough into the bodies of the vertebra above and below the defect. A silastic tubing 19 mm in diameter and appropriate length is taken and a central hole is made into the middle of the tube on the lateral aspect, similarly holes are made on the Inferior and superior ends with serrations to act as a vent for air extrusion. The silastic tube is inserted in the defect created avoiding any kink in the tube. The central hole is used for pressurized cement injection by a syringe .Care is taken to avoid any extrusion of cement into the spinal canal. Cement is allowed to harden. This method has multiple

advantages firstly the cement is in a closed compartment which decreases the chances of spillage into the spinal canal . It reinforces the vertebral bodies above and below because of cement pressurization. Its engagement into the vertebra above and below makes it a stable construct. In case of tumor infiltration of the marrow of the adjacent vertebral body due to poor bone quality this construct can prove advantageous. Gokaslan using a chest tube have reported encouraging clinical results with significant improvement in pain and neurological status of the patients. No complications were seen regarding construct failure in this series.



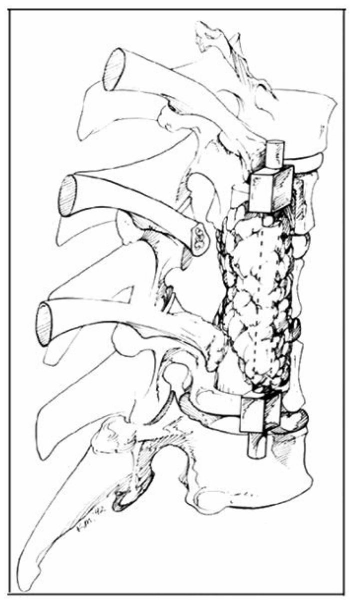


Fig 3: Use of Silastic Tube and PMMA for vertebral body reconstruction. From Errico, T.J. Cooper P.R (1993.). A New Method of Thoracic and Lumbar Body Replacement for Spinal Tumors: Technical Note. Neurosurgery 32: 678-68. (With Permission Courtesy LWW)

In the thoracic spine the approach usually used is lateral which in a way protects the cord from the harmful effects of the PMMA but in case of the cervical and upper thoracic spine the spinal cord is in a dependant position and there is a realistic chance of PMMA going posteriorly and damaging the cord. Miller[33] described a technique using coaxial double-lumen chest tubes for vertebral reconstruction to avoid this complication in cervical and upper thoracic spine. They did all surgical procedures in supine position and used standard anterior cervical, median sternotomy or trap door procedures. The technique is as follows: Once Tumor resection was completed, posterior longitudinal ligament (PLL) was removed and dura exposed. End plates of vertebra above and below removed and centrally placed holes were made in vertebra above and below. Size 28 and 40 Fr chest tubes taken. The 40 Fr chest tube cut and a strip of 10 mm is removed. This larger sized tube is used as the outer tube to protect the spinal cord from compression and thermal injury. The 28 Fr chest tube is placed centrally in the holes above and below and the 40 Fr chest tube is placed coaxially outside the central tube. Cement is injected in the central tube.

The outer tube is removed once cement becomes viscid. Manual distraction is applied by the anesthesiologist till cement is solidified. Continuous irrigation with saline is used through the cement setting time. An anterior screw and plate system was added to prevent distraction failure in all patients with 9 patients had a supplementary posterior fixation. No external Orthosis were used postoperatively. Significant improvement in pain and neurological status was reported preoperatively. They had two significant failures of the construct along with local recurrence which lead to reoperations. One patient had multiple recurrence and esophageal perforation due to failure of the construct. The authors have therefore recommended using 4mm titanium rod in the cement-tube construct to prevent failure in reconstructions involving more than 3 levels.

S.Boriani[34] introduced the Carbon Fiber reinforced polymer (CFRP) stackable cage system for reconstruction of anterior column defects. The CFRP system consists of thoracic and lumbar octagonal carbon fiber cages with open chambers which can accept bone graft. This is a modular system and it can be stacked with an anterior plate or posterior instrumentation system with screws angulated 30 degrees from the posterior construct which would mimic the pedicles .There are multiple advantages of this system like facilitation of load sharing and subsequent early healing and hypertrophy of the bone graft leading to union, modulus of elasticity closely matching bone, radiolucency of the cages which makes postoperative evaluation convenient, MRI compatibility, biological inertness, non-carcinogenicity and biomechanically a strong construct[35]. Boriani[36] described good clinical outcome using this construct in 42 patients with no incidence of failure of construct, re-operations, or any complications related to CRFP system.

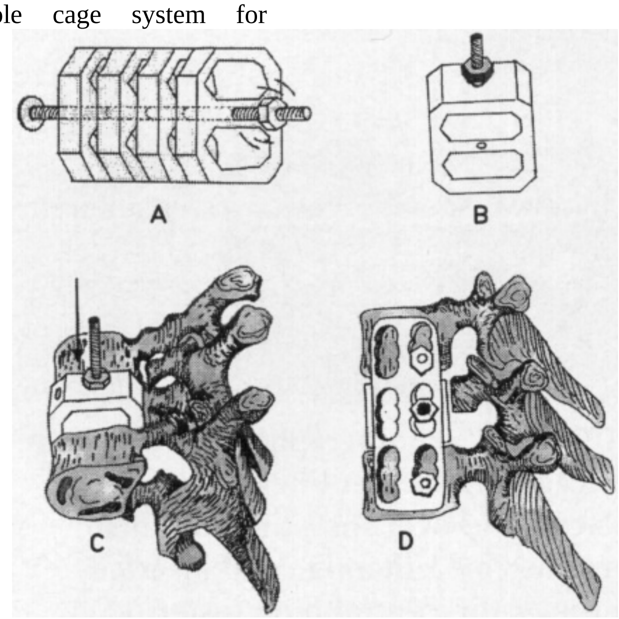


Figure 4: CFRP Cage insertion technique. From Ciappetta P, Boriani S, Fava GP (1997 Nov) A carbon fiber reinforced polymer cage for vertebral body replacement: technical note. Neurosurgery; 41(5):1203-6. (Reproduced with permission courtesy, LWW)

Lutz[37] introduced a new radiolucent system of vertebral body replacement consisting of composite bioglass-polyurethane body and a new configuration of polymeric fastening hardware. Advantages cited were no problems like loosening, chances of damage to the spinal cord due to thermal injury, no interfere with radiologic assessment with X-rays, CT scan and MRI . It consists of vertebral body replacement prosthesis made of polyurethane and bioglass composite (PU-C, BiovisionTM, Illnenau, Germany) and has got an attached plate and multiple screws made up of carbon fiber reinforced polyetherketone (CF-PEEK). The bioglass component (40%) promotes bone bonding with prosthesis. The replacement body is secured with multiple screws in the side plate to the vertebra above and below. Two screws angulated at 40 degrees act as lag screws and compress the prosthesis to the vertebra above and below. A biomechanical study performed with this prosthesis showed significant resistance to torsional deformation and ventral interface movement when compared with the other available spacers. In patients with severe collapse and kyphotic angulation at the cervicothoracic junction, achieving these goals can be challenging. The telescopic plate spacer (TPS) (Interpore Cross International, Irvine, CA) is a device designed to facilitate spinal fixation after tumor resection at the cervical or upper thoracic spine[35,38] . Several features of the TPS appear to be biomechanically advantageous: in-line distraction, use of vertebral anatomy, integration of plate and spacer, and screw angle options. Four design features of the TPS exploit natural anatomic and biomechanical features of the spine. First, the TPS engages the strongest part of the vertebra: the ventroanterior edge, or "ventral lip," of the vertebra, which provides an excellent platform for reconstruction. Second, the TPS uses the anatomic slope of the endplate of the vertebra above: the cephalad surface of the TPS, angled at 10 degrees, conforms to the diagonal slope of the vertebral endplate. Third, the TPS has a 45-degree-angle screw option; in many instances, this screw angle is more favorable because it allows use of a longer screw without violation of the posterior cortex. Coumans[38] in their series used unicortical screws. TPS does have less chances of subsidence due to broad surfaces and by not taking support from the weaker central core of the vertebrae. Fully constrained screws and the integration of plate and spacer prevent toggling. The flanges also prevent posterior displacement of the construct and avoid neurologic compression.

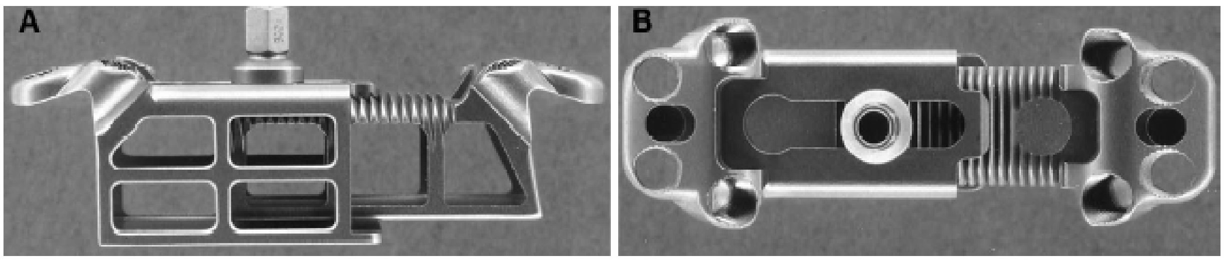


Figure 5: Telescopic Plate Spacer (TPS): (A) Side view. (B) Front View. (Reproduced with Permission) Coumans JV, Marchek CP, Henderson FC.(2002 Aug) Use of the telescopic plate spacer in treatment of cervical and cervicothoracic spine tumors. Neurosurgery; 51(2):417-26 (Courtesy LWW).

Titanium Mesh cages are able to withstand significant axial loads. They provide an excellent method of anterior reconstruction when combined with anterior or posterior instrumentation systems. Biomechanically[39] it has been shown that titanium mesh cage can resist more than 1000 N of axial load. They can be used with bone grafts or PMMA. Mesh cage offers superior rotational stability when compared to bone or acrylic[40]. The cage is anchored with its sharp edges into the vertebral end plates. To prevent subsidence the titanium ring or manhole cover can be applied to either end of the titanium mesh. Most authors advice against the removing of the vertebral end plates. Caution should be observed during placement of the mesh cage to prevent cord compression. Intraoperative radiographs and somatosensory evoked potential monitoring is helpful in this regards. Anterior and / or posterior supplementary fixation should be done accordingly. Various complications reported are: cage migration and subsidence, adjacent level degeneration, and stenotic myelopathy and hardware failure. Further, metallic cages lead to artifacts during computed tomography (CT) and magnetic resonance imaging (MRI). Additionally, metallic cages may lead to stress shielding of the graft inside the cage, resulting in a decreased interbody bone matrix formation or nonunion.

Advancement in surgical techniques and technologies has led to the use of expandable titanium vertebral cages. They avoid the problem of cage subsidence as associated with titanium mesh cages and provide broader surfaces and duller edges. There other advantage is the correction of the deformity and restoration of immediate stability. The titanium cages whether expandable or not require supplementary fixation for stability, anteriorly or posteriorly. It can be used from cervical to the lumbar spine. The expandable cages consist of a two end pieces and a central core. The end pieces are available in various angles to correct multiple types of deformities. After vertebral resection appropriate sized expandable cage is used and the angled end piece suited to correct deformity can be used. The cage is expanded and once appropriate correction of deformity has taken place the end pieces are locked to the central core with screws. The vertebral body replacement expandable cages have been biomechanically proven in stability and load bearing[41]. Durr[42] reported good results in patients with Myeloma using expandable cages after decompression of the vertebral body and using supplementary fixation. Pain relief was achieved in 26 of 27 patients.

Figure 6: Synex expandable cage (With Permission from Synthes, West Chester, PA . copyright Synthes)

Yonenobu[43] have presented their results in 84 patients with use of ceramic prosthesis in patients with spinal metastasis. After resection of the vertebral body, reconstruction/ replacement was done by using a alumina ceramic prosthesis. They did not encountered any complications. Ambulation status was improved in 64% whereas motor grade improved in 81%. Pain relief occurred in 94% of the patients.

Cooper recommended that above T11 if there is only anterior and middle column involvement vertebral body replacement alone without instrumentation is sufficient. If above T11 there is three column involvement then in addition to anterior reconstruction a supplementary posterior instrumentation is required. Below T11 for one or two column destruction, vertebral body reconstruction and anterior instrumentation is required. In three columns involvement below T11 vertebral body reconstruction, anterior instrumentation and supplementary posterior stabilization is required.

CONCLUSION

Surgical treatment of Spinal Metastasis is still controversial. Metastatic Spinal disease mostly affects the Vertebral body and Pedicle (85%). Laminectomy alone has not found to be of any benefit due to its destabilizing effect on already unstable spine and secondly due to inadequate decompression. Anterior approaches address the neurologic compression more directly and are also associated with less chances of wound complications even after irradiation. Various options can be used for vertebral reconstruction after corpectomy. These include bone grafts, Bone cement alone or in combination with various implants, Expandable or non-expandable cages and various available metallic implants. The surgeon has to choose the best treatment option considering the fact that Surgery in spinal Metastasis is primarily Palliative.

Abbreviations:

RT- Radiation therapy.
PMMA- Polymethylmethacrylate.
ALL- Anterior longitudinal ligament.
PLL- Posterior longitudinal ligament.

REFERNCES

1. Aaron AD: The management of cancer metastatic to bone. JAMA, 1994; 272:1206–1209.
2. Ratanatharathorn V, Powers WE. Epidural spinal cord compression from metastatic tumor: diagnosis and guidelines for management. Cancer Treat Rev, 1991; 18:55–71.
3. Barron KD, Hirano A, Araki S. Experiences with metastatic neoplasms involving the spinal cord. Neurology 1959; 9:91–106.
4. Lenz M, Freid JR Metastases to the skeleton, brain and spinal cord from cancer of the breast and the effect of radiotherapy. Ann Surg 1931;93:278–293.
5. Sundaresan N, Krol G, DiGiacinto GV. Metastatic tumors of the spine, in Sundaresan N, Schmidek HH, Schiller AL, et al (eds). Tumors of the Spine: Diagnosis and Clinical Management. Philadelphia: WB Saunders, 1990; pp 279–304.
6. Wong DA, Fornasier VL, MacNab I. Spinal metastases: the obvious, the occult, and the impostors. Spine 1990; 15:1–4.
7. Schaberg J, Gainor BJ. A profile of metastatic carcinoma of the spine. Spine 1985;10:19–20.
8. Sundaresan N, Digiacinto GV, Hughes JE. Treatment of neoplastic spinal cord compression: results of a prospective study. Neurosurgery 1991; 29:645–650.
9. Barron KD, Hirano A, Araki S. Experiences with metastatic neoplasms involving the spinal cord. Neurology 1959; 9:91–106.
10. Gilbert RW, Kim JH, Posner JB. Epidural spinal cord compression from metastatic tumor: diagnosis and treatment. Ann Neurol. 1978; 3:40–51.

11. Tomita K, Kawahara N, Kobayashi T, Yoshida A, Murakami H, Akamaru T. .Surgical strategy for spinal metastases. Spine. 2001 Feb;1;26(3):298-306.
12. Regine WF, Tibbs PA , Young A, Payne R, Saris S , Kryscio RJ , Patchell RA. Metastatic Spinal Cord Compression: A Randomized Trial of Direct Decompressive Surgical Resection Plus Radiotherapy vs. Radiotherapy Alone. Proceeding of the 45th Annual ASTRO meeting. Oct. 2003.
13. Stark RJ, Henson RA, Evans SJ . Spinal metastases: a retrospective survey from a general hospital. Brain, 1982;105:189–213.
14. Constans JP, de Divitiis E, Donzelli R.: Spinal metastases with neurologic manifestations. Review of 600 cases. J Neurosurg, 1983;59:111–8.
15. Young RF, Post EM, King GA. Treatment of spinal epidural metastases; randomized prospective comparison of laminectomy and radiotherapy. J Neurosurg, 1980;53:741-8.
16. Gokaslan ZL, York JE, Walsh GL, McCutcheon IE, Lang FF, Putnam JB Jr, Wildrick DM, Swisher SG, Abi-Said D, Sawaya R.Transthoracic vertebrectomy for metastatic spinal tumors. J Neurosurg. 1998 Oct; 89(4):599-609.
17. Cooper P, Errico TJ, Martin R. A systematic approach to spinal reconstruction after anterior decompression for neoplastic disease of the thoracic and lumbar spine. Neurosurgery 1993 ;32:1–8.
18. Walsh GL, Gokaslan ZL, McCutcheon IE. Anterior approaches to the thoracic spine in patients with cancer: Indications and results. Ann Thorac Surg.1997;64:1611–1618.
19. York JE, Walsh GL, Lang FF. Combined chest wall resection with vertebrectomy and spinal reconstruction for the treatment of Pancoast tumors. J Neurosurg 1999; 91(1 Suppl):74–80.
20. Tokuhashi Y, Matsuzaki H, Toriyama S, Kawano H, Ohsaka S.Scoring system for the preoperative evaluation of metastatic spine tumor prognosis. Spine.1990; 15:1110–3.
21. Tomita K, Kawahara N , Kobayashi T, Yoshida A, Murakami H , Akamaru T , Surgical Strategy for Spinal Metastases, Spine, February 2001; Vol 26(3): p 298-306.
22. Bunger C Laursen M, Hansen E S, Neumann P, Christensen, F B, Hoy K, Helmig, P. A new algorithm for the surgical treatment of spinal metastases. Current Opinion in Orthopedics. April 1999;10(2):101-105.
23. Lewandrowski KU, Hecht AC, DeLaney TF, Chapman PA, Hornicek FJ, Pedlow FX. Anterior spinal arthrodesis with structural cortical allografts and instrumentation for spine tumor surgery. Spine. May 2004;29(10):1150-9.
24. Nakamura H, Yamano Y, Seki M, Konishi S.Use of folded vascularized rib graft in anterior fusion after treatment of thoracic and upper lumbar lesions. Technical note. J Neurosurg Spine.2001;94(2):323-7.
25. Spear MA, Dupuy DE, Park JJ, Halpern EF, Spiro IJ. Tolerance of autologous and allogeneic bone grafts to therapeutic radiation in humans. Int J Radiat Oncol Biol Phys.1999 Dec;1;45 (5):1275-80.
26. Harrington K.D. Metastatic Tumors of the Spine: Diagnosis and Treatment. J Am Acad Orthop Surg.1993;1:76-86.
27. Harrington K D .Anterior decompression and stabilization of the spine as a treatment for vertebral collapse and spinal cord compression from metastatic malignancy. Clinical orthop. 1988 Aug;(233):177-97.
28. Perrin, R G; McBroom, R J. Spinal fixation after anterior decompression for symptomatic spinal metastasis. Neurosurgery 1988 Feb;22 (2):324-7.
29. Yen D, Kuriachan V, Yach J, Howard A. Long-term outcome of anterior decompression and spinal fixation after placement of the Wellesley Wedge for thoracic and lumbar spinal metastasis. J Neurosurg Spine.2002 Jan; 96(1):6-9.
30. Akeyson EW, McCutcheon IE. Single-stage posterior vertebrectomy and replacement combined with posterior instrumentation for spinal metastasis. J Neurosurg. 1996 Aug;85(2):211-20.
31. Errico, T.J. Cooper P.R. A New Method of Thoracic and Lumbar Body Replacement for Spinal Tumors: Technical Note. Neurosurgery 1993;32: 678-68.
32. 15. Ratliff, J K ,Cooper P R. Metastatic spine Tumors. Southern Medical Journal. March 2004;Vol 97(3), pp 246-253.
33. Miller DJ, Lang FF, Walsh GL, Abi-Said D, Wildrick DM, Gokaslan ZL. Coaxial double-lumen methylmethacrylate reconstruction in the anterior cervical and upper thoracic spine after tumor resection. J Neurosurg Spine.2000;92(2):181-90.
34. Boriani S, Biagini R, Bandiera S, Gasbarrini A, De LF . Reconstruction of the anterior column of the thoracic and lumbar spine with a carbon fiber stackable cage system. Orthopedics.2002 Jan;25(1):37-42.
35. Ciappetta P, Boriani S, Fava GP. A carbon fiber reinforced polymer cage for vertebral body replacement: technical note. Neurosurgery.1997; 41(5):1203-6.
36. Boriani S, Bandiera S, Biagini R, De Iure F, Giunti A. The use of the carbon-fiber reinforced modular implant for the reconstruction of the anterior column of the spine. A clinical and experimental study conducted on 42 cases. Chir Organi Mov.2000 Oct-Dec;85 (4):309-35.
37. Claes L, Schultheiss M, Wolf S, Wilke HJ, Arand M, Kinzl L.J A new radiolucent system for vertebral body replacement: its stability in comparison to other systems. Biomed Mater Res.1999 Spring;48(1):82-9.
38. Coumans JV, Marchek CP, Henderson FC.Use of the telescopic plate spacer in treatment of cervical and cervicothoracic spine tumors. Neurosurgery.2002 Aug;51(2):417-26.
39. Hollowell JP, Vollmer DG, Wilson CR, Pintar FA, Yoganandan N. Biomechanical analysis of thoracolumbar interbody constructs. How important is the endplate?Spine.1996 May;1;21 (9):1032-6.
40. Magge S, Woodard E, Interbody devices used in malignancy of thoracolumbar spine, Techniques in Neurosurgery. June 2001; 7(2):169-178.
41. Thongtrangan I, Balabhadra RS, Le H, Park J, Kim DH. Vertebral body replacement with an expandable cage for reconstruction after spinal tumor resection. Neurosurg Focus.2003 Nov; 15;15 (5):E8.
42. Durr HR, Wegener B, Krodel A, Muller PE, Jansson V, Refior HJ. Multiple myeloma: surgery of the spine: retrospective analysis of 27 patients. Spine. Feb 2002 ;1;27(3):320-4; discussion 325-6.
43. Hosono N, Yonenobu K, Fuji T, Ebara S, Yamashita K, Ono K.(1995 Nov) Vertebral body replacement with a ceramic prosthesis for metastatic spinal tumors. Spine 1995 Nov;15;20(22):2454-62.

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