ENDOSCOPICALLY ASSISTED SINGLE-STAGE POSTERIOR TRANSPEDICULAR 2-LEVEL VERTEBRAL COLUMN RESECTION AND CAGE RECONSTRUCTION FOR CONTIGUOUS THORACIC VERTEBRAL BODY METASTASES

A. Kelly, FC Neurosurgery (SA), Dr. George Mukhari Academic Hospital, Sefako Makgatho Health Sciences University, Pretoria, South Africa, **A. Younus**, FC Orthopaedic Surgery (SA), Helen Joseph Hospital, University of the Witwatersrand, Johannesburg, South Africa, and **P. Lekgwara,** FC Neurosurgery (SA), Dr. George Mukhari Academic Hospital, Sefako Makgatho Health Sciences University, Pretoria, South Africa

Correspondence to: Dr. Adrian Kelly, P.O. Box Medunsa, Pretoria, South Africa. Email: adriankelly1000@yahoo.co.uk

ABSTRACT

Spinal metastases account for approximately 50% of skeletal lesions and demonstrate an increased incidence in the elderly. Poor long-term survival, and a high incidence of operative complications, see the majority of patients managed by radiation, with surgical intervention reserved as a last resort. Even in patients with a Tokuhashi score dictating surgical excision, significant controversy exists regarding the ideal surgical intervention that should be performed. In terms of clarifying this controversy the most essential consideration is proposed to be survival prognosis. In the thoracic spine the commonly employed surgical interventions are a posterolateral thoracotomy and trans-pleural vertebral body curettage or resection with a cage and lateral plate reconstruction, a posterior transpedicular tumour resection and vertebral body reconstruction, or a combined approach. While more extensive, and not without complications, a posterior Vertebral Column Resection (VCR) is a viable surgical option in these patients. During en-bloc or piecemeal VCR surgery, a surgeon invariably encounters a blind spot during which he/she must rely on palpation to relieve the ventral dural compression.

We report a case of an elderly female patient who presented to our unit acutely paraplegic secondary to 2-level pathological thoracic burst fractures from metastatic ovarian carcinoma. She was taken to the operating room for a 2-level VCR, and during the procedure we used a 30-degree endoscope to visualize the anterior dural surface, utilizing the benefit of magnification to ensure the dura had been thoroughly decompressed. According to our PubMed review this is the first report of this novel adjunctive technique.

Key words: Single-stage, Endoscopically assisted, Metastatic disease, Vertebral column resection

INTRODUCTION

While cancers can metastasize to any bone, the spine is noted to be the most common site (1). Several studies note that spinal metastases account for approximately 50% of bony metastases overall (2,3). In patients with cancer, a higher incidence of spinal metastases is noted to occur in older patients compared to younger patients, and a further slight male predominance is noted, with one study by Aebi (4) reporting a male to female ratio of 1.3:1. With regards to ovarian cancer, patients are commonly in their 5th or 6th decade at the time of diagnosis. Approximately 60% of patients present with metastatic disease at the time of diagnosis, primarily intra-pelvic and intra-abdominal peritoneal spread, with a 5-year survival rate below 50% (5,6). The vertebral venous system is regarded as the primary means by which ovarian cancer disseminates, in a retrograde fashion, to the spinal column. Despite this being the plausible pathway, vertebral metastases in ovarian cancer are exceedingly rare, with a reported incidence of only 1.1% - 1.6% (7,8). When vertebral column metastases do occur, advanced vertebral body destruction leads to a pathological burst fracture, spinal cord compression secondary to retropulsed tumour and bone, instability, and in some cases significant deformity. The clinical expression of vertebral column involvement is severe spinal pain, difficulty ambulating, and as the disease progresses neurological impairment (9). Percentage incidences of the symptomatology of vertebral metastases is reported in one study by

Greenlee *et al* (10) which notes 90% of patients to present with pain, and 20% of patients to present with a neurological deficit secondary to spinal cord compression.

Regarding the treatment of spinal metastases, poor long-term survival, and a high incidence of operative complications, have both resulted in stereotactic radiotherapy and chemotherapy being preferred modalities of treatment, with operative intervention being largely considered a last resort (1). Despite this being generally accepted in the absence of progressive neurology secondary to spinal cord compression, instability, and deformity, several studies (11-13) advocate surgical intervention when these specific indications are present. Here the goals of surgery, proposed in these same studies, is to restore neurological function, stabilize the spine, and relieve pain. With these goals in mind, several studies (14,15) note that removal of the entire tumour is often not possible and hence radical operations are not advised. The underlying accepted premise in these studies, against which the goals of surgery must be balanced, is the fact that whatever form of spinal surgery is performed does not significantly change the survival rate (14,15). The most essential consideration for determining the type of surgery that should be performed is proposed to be survival prognosis (16). Patient age, tumour histology, male gender, medical co-morbidities, and surgical complications, have all been demonstrated as significant prognostic factors in this regard (17,18). Contra-indications to surgical intervention include advanced co-morbidities that preclude general anaesthesia, a Karnofsky performance score of 30 or below, concomitant sepsis, and a life expectancy of less than 6-months. In the thoracic spine the most commonly employed surgical interventions are a posterolateral thoracotomy and trans pleural vertebral body curettage or resection with a cage and lateral plate reconstruction, a posterior transpedicular tumour resection and vertebral body reconstruction with bone graft or cement augmented by a posterolateral pedicle screw and rod fusion, or a combined anterior and posterior approach (1). Performing a circumferential posterior Vertebral Column Resection (VCR) was first described by Bradford, in a study published by Bradford in 1987 (19), where it was used to treat 13 patients with rigid spinal deformities. Several subsequent studies (20-23) have supported the usefulness of the procedure, and while also confirming its established role in rigid spinal deformities, have extended the indications to include a range of pathologies including congenital scoliosis, degenerative scoliosis, vertebral body tumours, and in very recent studies (20-23)osteoporotic burst fractures. The advantage of the procedure is that the surgeon establishes his/her visualization of the spinal cord early in the procedure, and as he/she continues with the bilateral transpedicular resection, this visualization progressively increases and is maintained throughout, translating into a reduced incidence of direct spinal cord injury (24).

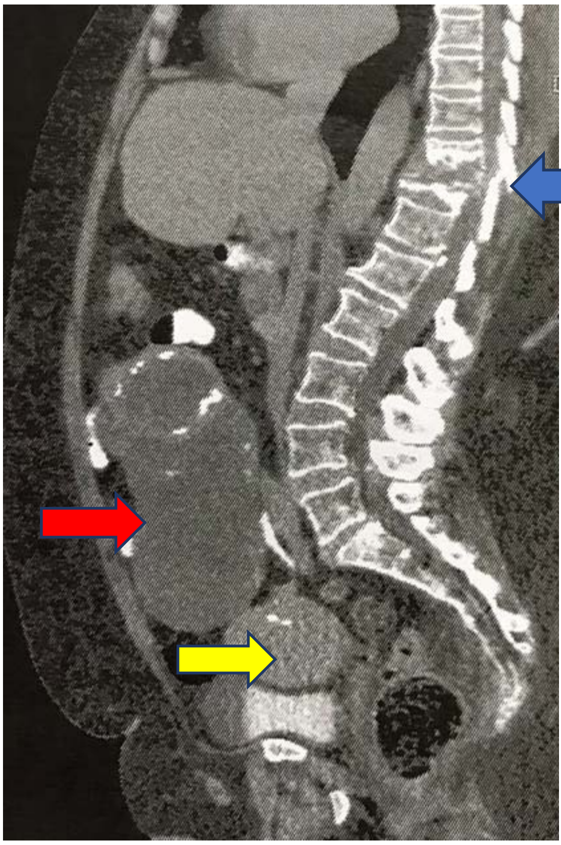
We report a case of a 72-year old female patient, with a history of ovarian cancer, who presented to our unit with progressive paraplegia and an acute inability to walk. Our radiological investigations demonstrated isolated T10 and T11 pathological burst fractures with spinal cord compression, instability, and significant acute kyphotic angulation. She was taken to the operating room for a single stage posterior transpedicular 2-level VCR and self-expanding cage reconstruction. During the procedure we used a 30-degree endoscope to visualize the anterior surface of the spinal cord and, by direct endoscopic visualization, confirm it was free of compression. While a recent study by Kakadiya *et al* (23) reports the utility of this novel endoscopic technique in the context of performing a VCR for osteoporotic burst fractures, according to our review of the PubMed literature we are the first to report its use in the context of a 2-level VCR performed for spinal metastases.

CASE REPORT

A 72-year old female patient presented to our unit with a 2-month history of progressive lower limb weakness, which had now progressed to such an extent that she was now unable to walk for the preceding 3-days. She also reported a history of progressive thoracolumbar backache for 6-months. She denied any bladder or bowel symptoms. In terms of her surgical history she had a history of ovarian cancer and had undergone a surgical resection 4-years prior to this presentation. In terms of her medical history she was known with hypertension, which was controlled medically, and had been recently tested and was HIV negative. As part of the admission she was tested for COVID-19 and the PCR result from both that nasal and pharyngeal swabs were negative. On general examination an increased body mass index and a gibbus at the thoracolumbar junction with associated paraspinal muscle spasm was present. Examination of her abdomen revealed a firm fixed pelvic mass extending 11cm above the pelvic brim, however no hepatosplenomegaly was noted. Neurological examination revealed a spastic paraplegia with power 2/5, increased lower limb tone, brisk lower limb deep tendon reflexes, and bilaterally present Babinski signs. Sensory examination revealed her to have an incomplete T8 sensory level. We classified her neurological status as a Frankel C. A staging CT chest abdomen and pelvis was performed which excluded liver and lung metastases, but confirmed a mass originating in the pelvis, extending into the abdominal cavity with scattered calcifications, separate to the bladder which was noted inferiorly. On the sagittal view pathological burst fractures of T10 and T11 was noted with 38-degrees of acute kyphotic angulation (Figure 1).

Figure 1

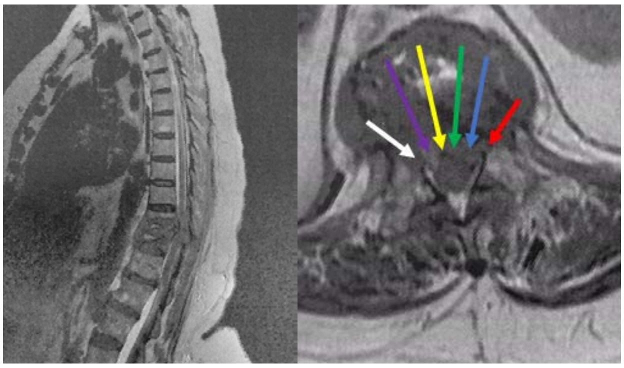
Pre-operative CT abdomen sagittal view, demonstrating a probable ovarian mass originating in the pelvis and extending into the abdominal cavity (red arrow), separate to the bladder (yellow arrow). The pathological T10 and T11 burst fractures compromising the spinal canal, with 38-degrees of acute kyphotic angulation, are clearly visible (blue arrow)



Due to her progressive neurology an MRI spine was performed which confirmed the CT findings, and on the axial view the tumour was staged according to the Weinstein Boriani classification (Figure 2).

Figure 2

Pre-operative MRI T2W images showing, on the sagittal view, the T10 and T11 pathological burst fractures with retropulsion of bone compressing the spinal cord. The acute kyphotic angulation centered across the pathologically fractured levels can be appreciated (red arrow). On the axial view the tumour is noted to be filling the entire vertebral body with extradural extension into the spinal canal, compressing the spinal cord. There is furthermore no extension into the adjacent soft tissues or pedicles. We classified this as involving Weinstein Boriani segments 4C intra-osseous deep (red arrow), 5D extra-osseous extradural (blue arrow), 6D extra-osseous extradural (green arrow), 7D extra-osseous extradural (yellow arrow), 8D extra-osseous extradural (purple arrow), and 9C intra-osseous deep (white arrow)

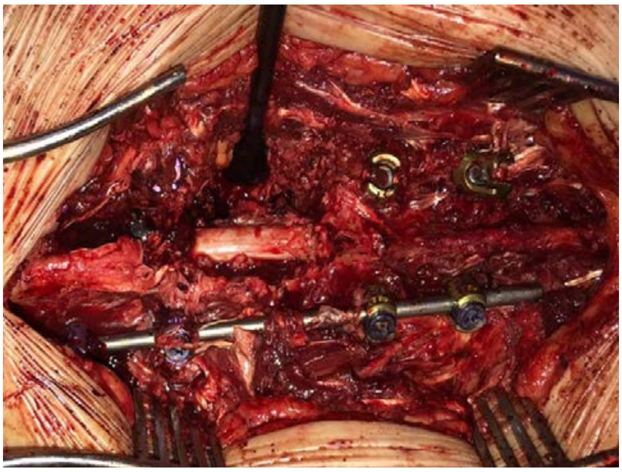


Based on her clinical presentation and radiological investigations she was assessed by the Tokuhashi scoring system and noted to be in a 1. Poor general condition due do her needing assistance to perform all activities of daily living (score=0), 2. To have no extraspinal bone metastases (score=2), 3. To have a single focus of metastases in the adjacent vertebral bodies (score=2), 4. No metastases to major internal organs (score=2), 5. A primary site of other (score=2), and 6. To be Frankel C neurologically (score=1), which in total gave her a Tokuhashi score of 9. While this score was assessed was borderline for palliative or excisional surgery, the fact that she had a single focus in the spine and no metastases to major internal organs, allowed us to offer her excisional surgery. In terms of the specifics of the surgery, the fact that there was no obvious involvement of the pre- and paraspinal structures, lead us to decide that we would perform an endoscopically assisted single-stage posterior transpedicular 2-level VCR and cage reconstruction.

Operative procedure: She was taken to the operating room and post induction of anaesthesia, neurophysiological monitoringutilizing motor evoked potentials, scalp and muscle needle electrodes and leads, were placed. She was placed prone on the operating table and the collapsed T10 and T11 levels were identified with lateral fluoroscopy. A midline skin incision was made and the lamina and rib heads from T8-T12, and the lamina and facet joints of L1, were exposed. Under anteroposterior fluoroscopy T8, T9, T12 and L1 pedicle screws were placed in accordance with the standard technique. A bilateral costotransversectomy over the T10 and T11 levels was performed by performing a subperiosteal dissection undermining the periosteum and pleura from the anterior surface of the 10th and 11th ribs. A rib cutter was used to transect the medial 5cm of the 10th and 11th ribs, which were then carefully disarticulated from the transverse processes of T10 and T11 with care taken to protect the underlying parietal pleura. A wide laminectomy of T10 and T11 was performed, including resection of the medial sides of the T10 and T11 pedicles, during which the dorsal and the posterior part of the lateral surfaces of the dura were visualized (Figure 3).

Figure 3

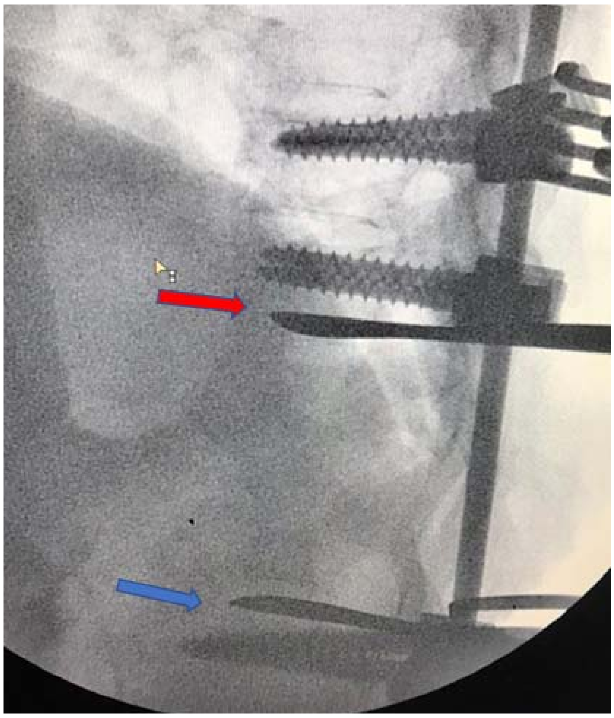
Intra-operative photograph after the T10 and T11 costotransversectomies, T10 and T11 laminectomies, and the T10 and T11 pedicle resections, on the side opposite to the rod. The clearly visualized dura, which is still compressed anteriorly, is clearly visualized



The T10 nerve roots were ligated with silk suture bilaterally and transected. Blunt dissection was then used to expose the lateral sides of the T10 and T11 vertebral bodies. A rod was placed on one side and fixed across the collapsed levels into the superior and inferior screw heads with screw caps. On the opposite side to where the rod was placed, a transpedicular resection was utilized, to gain entry, into the ipsilateral half of the T10 and T11 vertebral bodies. By working in the space between the medial surface of the resected T10 and T11 pedicles, and the lateral sides of the T10 and T11 vertebral bodies, piecemeal resection of the diseased T10 and T11 vertebral bodies on the first side was accomplished. Once a hemi-vertebrectomy of T10 and T11 had been achieved on one side, a rod was placed on the ipsilateral side, the rod removed from the contralateral side, where-after the same procedure was performed on the contralateral side to complete the resection of the T10 and T11 vertebral bodies from a purely posterior approach. Once the T10 and T11 vertebral bodies were resected, we used a Cobb dissector to create a plane, and resected the T9/T10, and T11/T12, intervertebral discs, thereby exposing the inferior endplate of T9 and the superior end plate of T12 respectively. We placed a Cobb dissector at the superior and inferior ends of the resection cavity and took a lateral fluoroscopic image to confirm we had achieved a complete resection, from the inferior end plate of T9, to the superior end plate of T12 (Figure 4).

Figure 4

Intra-operative fluoroscopic image taken with a Cobb dissector placed at the cranial and caudal ends of the resection cavity. The image confirmed that the T9/T10 discectomy, T10 and T11 corpectomies, and the T11/T12 discectomy had been achieved. The superior Cobb dissector is noted to be resting on the inferior end plate of T9 (red arrow), and the inferior Cobb dissector is noted to be resting on the superior end plate of T12 (blue arrow)



While we could not directly visualize the anterior surface of the dura we embarked on an innovative technique. By introducing a 30-degree endoscope into the resection cavity on the second side, we were able to directly visualize the anterior surface of the dura (Figure 5).

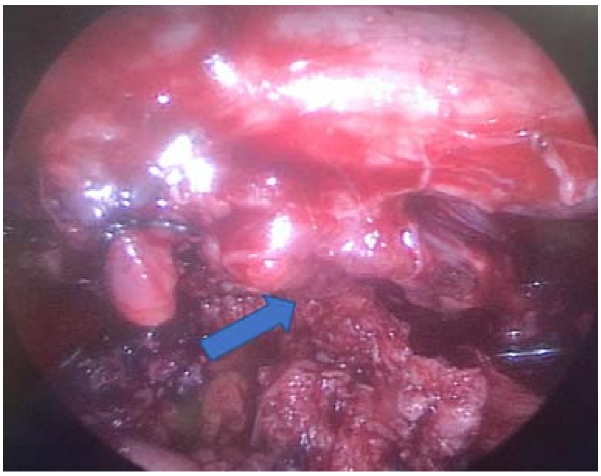
Figure 5

Intra-operative photograph of the introduction of the 30-degree endoscope used to directly visualize the anterior surface of the dura

What we saw on initial insertion of the endoscope was unexpected as we noted adherent tumor tissue on the anterior surface of the dura (Figure 6).

Figure 6

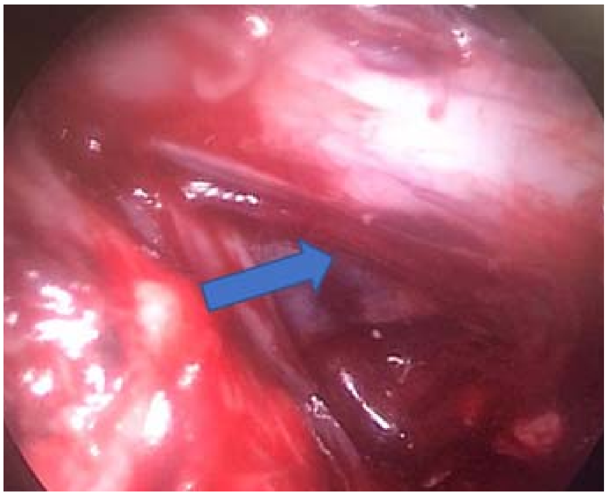
Intra-operative initial endoscopic image on introduction of the 30-degree endoscope where we noted tumour tissue still adherent to the anterior surface of the dura (blue arrow)



By this innovative endoscopic technique, we were able to endoscopically resect this adherent tumour tissue, as well as directly visualize that no residual anterior compression of the dura was present through-out the craniocaudal extent of the resection cavity (Figure 7).

Figure 7

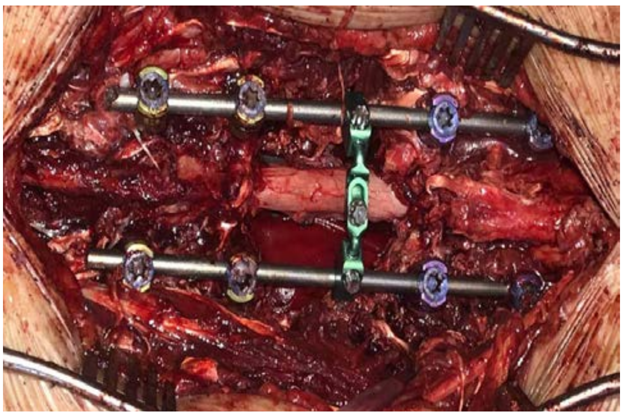
Intra-operative endoscopic image confirming the anterior surface of the dura (blue arrow) was free of adherent tumor tissue, and completely decompressed, through-out the craniocaudal extent of the resection cavity



Once the 2-level T10 and T11 VCR had been achieved, we placed and centered a self-expanding cage on the inferior end plate of T9 and the superior end plate of T12, expanded this, and locked it in place. We then placed the remaining rod and utilized slight compression, where-after we locked the rods into the screw heads. We decided to place a cross bar to augment the instrumented construct for increased stability (Figure 8).

Figure 8

Intra-operative photograph post the T10 and T11 posterior vertebral column resections with the cage in situ anteriorly, the T8-L1 posterolateral pedicle screw and rod instrumentation, augmented by a cross bar, in situ



A final fluoroscopic image confirmed the T10 and T11 levels had been completely resected, correct placement of the 2-level self-expanding cage, and that the T8-L1 posterolateral instrumentation had all corrected the acute kyphotic angulation and had stabilized the spine (Figure 9).

Figure 9

Intra-operative fluoroscopic image of the 2-level self expanding cage resting on the inferior end plate of T9, and the superior end plate of T12. The posterolateral T8-L1 pedicle screw and rod construct can also be visualized which had restored spinal stability. Note that the acute kyphotic angulation has been completely corrected

Due to an inadvertent pleural breach on the one side an ipsilateral intercostal chest tube was placed. We then placed allogenic bone graft, a postovac drain, and closed the wound in layers. The skin was closed with skin clips.

After spending one night in the Intensive Care Unit the patient was transferred to the general ward and commenced with rehabilitation. At 2-weeks post surgery we noted the power in her lower limbs to have improved to 3/5 although she could not ambulate. The histopathological result confirmed the resected tissue to be metastatic ovarian carcinoma. She was transferred to the gynaecology-oncology ward for further management of the ovarian mass and is for out-patient spinal review.

At her 3-month out-patient spinal review she reported that she had undergone a radical resection of the ovarian lesion and had received local radiotherapy to both the pelvic tumour bed and re-constructed vertebral level. Neurological examination revealed that the power in her lower limbs had improved to 4+/5 and she reported being independently ambulant at home, however used a walker when going outside.

DISCUSSION

Regarding the optimal treatment of spinal metastases, stereotactic radiotherapy has revolutionized many traditional treatment regimens. Many of the indications for surgery are being further challenged by stereotactic radiosurgery which overcomes tumour radio resistance by allowing high dose delivery in proximity to the spinal cord (24). While effective up-front stereotactic radiotherapy, in tumours with no tumuor - spinal cord interface, remain a challenge. Here separation surgery, to create a 1-2mm distance between the tumour and spinal cord, is an employed technique to allow the safe use of stereotactic radiotherapy stereotactic radiosurgery (25). Advances in stereotactic radiotherapy and stereotactic radiosurgery have seen the indications for surgery in these patients being reduced to radioresistant tumours with a high degree of spinal cord compression, and to address the problem of mechanical instability. Neither radiotherapy nor chemotherapy addresses the problem of mechanical stability and in these cases surgical stabilization is recommended to prevent neurological deterioration and progression of deformity (26). Unfortunately in our hospital we do not have stereotactic radiotherapy available, and hence in patients who demonstrate neurological deterioration secondary to spinal cord compression, we largely employ surgical resection and cage reconstruction of metastatic lesions, and thereafter employ standard radiotherapy for local control.

Two types of VCR have been described, en bloc VCR and piecemeal VCR. En bloc VCR is aimed to reduce tumour spread and recurrence, however the technique comes at the expense of a significantly increased operating time, and increased vascular complications as the surgeon must blindly dissect anterior to the vertebral body (26). Piecemeal VCR, as was performed in our case, involves the gradual removal of the tumour whereby the front of the vertebral body increasingly comes into direct view. This approach is regarded as safer with a comparatively lower incidence of vascular and neural injury (28). Regarding complications, excessive blood loss is commonly cited, and for this reason surgeon confidence and experience in the technique are regarded as pre-requisites to perform the procedure in several studies (21,27). Regarding vascular complications, direct injury to the inferior vena cava is cited as an avoidable complication if careful intra-operative technique is followed. A rare vascular complication cited in this same study is delayed aortic dissection which may occur in cases where the aorta is adhered to the tumour (9). Another complication that is reported, yet easily managed, is a pneumothorax secondary to an inadvertent pleural breach. This occurred in our case and was managed through 48 hours of intercostal chest tube drainage. Haemothorax should be considered as an entirely separate entity however the incidence, in posterior only surgeries, is lower than in anterior thoracic surgeries. Haemothorax may be caused by misplacement of screws, anterior pre-vertebral pleural breach, intercostal vessel damage during rib resection, or by pre-operative misplacement of the central venous catheter (30,31). Cage subsidence is another complication that is prevented by careful preparation of the superior and inferior end plates, taking care to avoid overzealous resection. Another technique to prevent subsidence is matching of the sizes of the end plates of the cage, to the size of the end plates of the vertebral bodies. One study by Fan *et al* (27) notes the importance of extraversion of the pedicle screws, away from the cage on either side, as a key surgical technique to assist in preventing subsidence.

Considering our use of the endoscope to assist in directly visualizing the anterior dura during the ventral decompression, during and after performing our 2-level VCR, we conducted a PubMed review and could only find one recent prospective study that considered this novel technique. In this study 80 patients with osteoporotic burst fractures,who underwent a single stage posterior three column reconstruction, had a 30-degree endoscope introduced to assist in visualization of the anterior dura during the ventral decompression. This study notes the fact that during the transpedicular phase of a posterior three column reconstruction, a point in the surgery invariably arises where the surgeon encounters a blind spot during which he/she must rely on palpation and relieve the ventral dural compression. Here the authors propose a 30-degree endoscope be introduced to assist in directly visualizing the decompression, rather than relying on palpation. In terms of outcome this study reported that 74/80 (93%) subjects experienced neurological improvement. The conclusion of this study was that while performing a posterior single-stage three column re-construction, the endoscope improves the surgeons operative field of view by providing essential magnification, and thereby ensures a more complete decompression without incurring dural injury (23).

CONCLUSIONS

We recognize that a VCR is not the ideal treatment of spinal metastases in centers where stereotactic radiotherapy and stereotactic radiosurgery are available. The ideal treatment of these lesions is to separate the tumour from the spinal cord, including stabilization of the vertebral column where needed, and employ adjuvant stereotactic radiotherapy to address the metastasis in a safe and effective manner. Regarding stabilization percutaneous pedicle screw and rod fixation, a limited decompression through a laminectomy, anterior augmentation by vertebroplasty or kyphoplasty, and placement of a vertebral body stent, are recognized to more safely restore spinal stability, with adjuvant stereotactic radiotherapy being an effective means to manage the involved vertebral body. In our center stereotactic radiotherapy is not available and hence we still employ VCR with adjuvant radiotherapy to manage many of these patients, albeit this being largely considered a historical treatment in many first World centers. VCR is a technically challenging technique with a significant complication rate. To reduce the incidence of adverse events, surgeons experience with the technique, and intra-operative neurophysiological monitoring, are considered mandatory. We propose, that in centers where a VCR is still being performed due to a lack of stereotactic radiotherapy being available, an additional technique, namely the introduction of a 30-degree endoscope, can be used to assist when performing the ventral decompression. An additional benefit of the technique is that it can be used to confirm the entirety of the ventral decompression through-out the craniocaudal extent of the VCR.

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