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Use of Carbon Fibre Implants in Metastatic Spinal Surgery

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Abstract

Introduction

Surgical management of metastatic spinal disease has become an increased area of focus for oncologists and spinal surgeons. We describe our initial experiences using carbon fibre implants in the treatment of metastatic spinal disease.

Case 1

A 67-year-old male with known metastatic colorectal cancer presented to his GP with a 3-month history of lower back pain. He was subsequently diagnosed with an L1 lesion and underwent a T11-L3 posterior spinal fusion using carbon fibre fixation.

Case 2

A 68-year-old previously well male presented to his local ED with a 10-week history of mid thoracic back pain. Imaging revealed a T7 lesion for which he underwent a T5-T10 posterior spinal fusion using carbon fibre fixation. Intra-operative histology revealed metastatic prostate cancer.

Case 3

A 76-year-old female who presented to her local ED with a six-week history of progressive lower limb weakness. Imaging revealed a T10 metastatic lesion for which she underwent a T8-T12 posterior spinal fusion using carbon fibre fixation.

Outcome

3 patients underwent spinal stabilization surgery using carbon fibre fixation in our institute. None of the patients had any post-operative complications and all underwent post-operative radiotherapy.

Introduction

There have been significant advancements in medical oncology over the previous 20 years. Patients are living longer with metastatic disease. As a result, the surgical treatment of metastases has become an increased area of focus. Surgical intervention involves relieving pressure off of the cord and stabilizing the spine using metal implants. Patients are often good surgical candidates for operative intervention. Surgery may involve oncologic resection or debulking tumor load, decompressing the spinal canal and neural tissue and stabilizing the spine with internal fixation either anteriorly, posteriorly or both.

Patients with metastatic disease can be referred urgently or emergently to a spinal center. Those referred in emergently, often have acute neurological deficits. Patients can have their spinal instability neoplastic score (SINS) calculated which helps guide management. The higher the score, the more likely surgical intervention is required. Those referred for consideration of surgical stabilization should have a reasonable life expectancy and be physically fit enough for intervention.

Implanted material was traditionally made of either titanium, stainless steel or cobalt chrome. There are several disadvantages to these materials when treating metastatic spinal disease. Artefact on post-operative imaging can obscure tumor recurrence with surveillance scans, but more importantly, metal implants can adversely affect the dose, accuracy and efficacy of prescribed adjuvant radiotherapy. These challenges lead to the use of carbon fibre fixation sets which aim to overcome these disadvantages.

Case Presentations

The cases discussed relate to three patients who underwent stabilization surgery using carbon fibre implants between March and December 2019. Patients were discussed at a weekly MDT involving at least two spinal surgeons, anesthetics, and radiation oncologists. The patients were selected based on their confirmed or presumed underlying primary malignancy, tumor suitability for fixation and prognosis.

Case 1

Patient 1 was a 67-year-old male who presented to his GP with a 3 month history of lower backpain on a background of metastatic colorectal carcinoma.

The patient subsequently underwent MRI imaging which revealed an L1 lytic lesion with compression of the conus medullaris.

After inter-hospital MDT discussion, the patient was transferred to our institute for decompression and T11-L3 posterior stabilization using carbon fibre implant sets. Pre and post operatively the patient had no neurologic deficit.

Below (Image 1) is an MRI performed day one post-operatively. It must be noted that there is considerable artefact on the post-operative imaging. This causes loss of visualization of the spinal cord. This occurred because carbon fibre implant sets still contain a small metallic component. This can cause potential metal susceptibility artifact which manifests as darkness on the image as seen below. This MRI was undertaken on a 3T scanner which is a higher power than a 1.5T scanner. Metallic artefact is more pronounced on higher magnet strengths. The difference in post-operative imaging suggests we should be using the 1.5T MRI for follow up imaging, as there is less artefact present. The patient underwent post-operative radiotherapy and had an uncomplicated post-operative course. The patient passed away in February 2020 due to their underlying primary cancer.

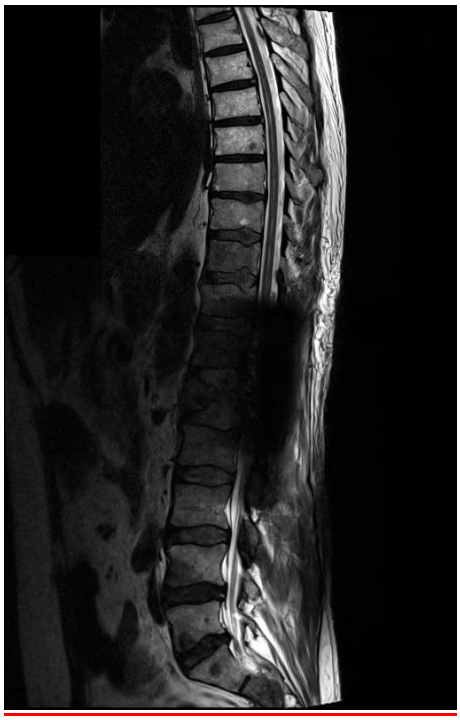

Image 1: Post-operative T2 weighted sagittal MRI (This scan was undertaken on a 3T MRI scanner. There is a loss of signal. The spinal cord cannot be visualized.)

Case 2

Patient 2 was a 68-year-old gentleman who initially presented to his local hospital with 10-week history of mid-thoracic back pain and 10kg unintentional weight loss.

The patient subsequently underwent CT scanning which demonstrated a destructive lytic lesion involving the T7 spinous process. Subsequent MRI (Image 2) showed a T7 lytic lesion with involvement of posterior elements and acute expansion with severe narrowing of the thoracic spinal canal. Given the patients demographics and appearance on imaging, a prostate primary was the most likely underlying malignancy.

After MDT the patient underwent a T7 decompression and T5-T10 posterior spinal fusion. T7 and T9 were skipped as these contained metastatic deposits.

Intra-operative histology samples confirmed metastatic prostate cancer. The ASIA score was T6 AIS D pre and post operatively. Post operatively the patient had a sensory deficit only. Below is his post-operative imaging. This MRI was undertaken on the 1.5T MRI scanner, as demonstrated there is significantly less artefact and we can visualize the spinal cord and adjacent structures. Below is an intra-operative image demonstrating a T5-T10 spinal fusion. The patient was lost to follow up.

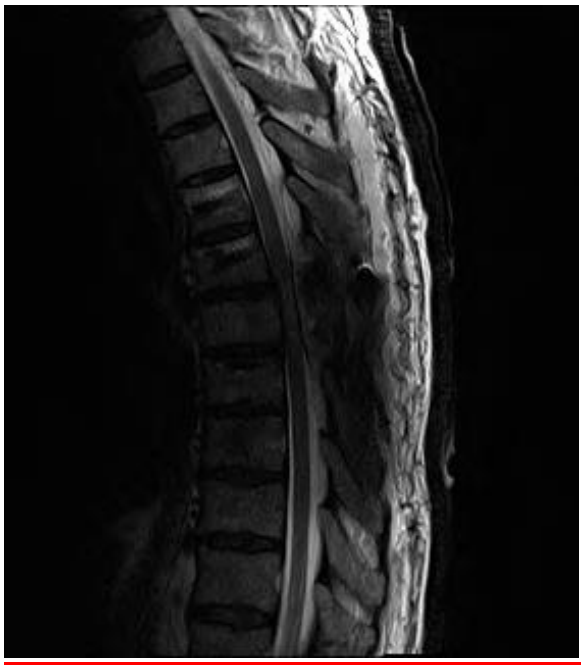

Image 2: Post-operative T-2 weighted sagittal MRI (This is an image from a 1.5T scanner. The spinal cord can easily be visualized. This can be compared to the earlier MRI in which imaging of the cord is obscured.)

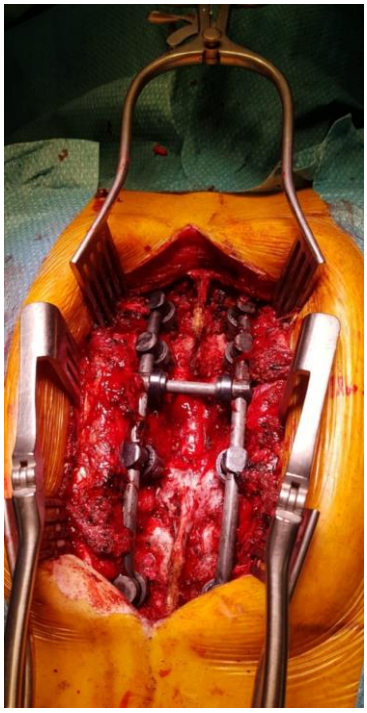

Image 3: Carbon fibre implants (An intra-operative picture)

Case 3

Patient 3 was a 76-year-old female. She initially presented to her local ED with progressive lower limb weakness and recurrent falls over the previous six weeks. On examination she was hyper-reflexic, had left leg weakness and upgoing plantars bilaterally.

An MRI whole spine reveled a T10 likely metastatic deposit with retropulsion with spinal cord compression (Image 4).

Based on multiple factors including imaging appearance, clinical examination and laboratory results lymphoma was suspected as the underlying malignancy.

After MDT discussions, the patient was transferred to our institute for surgical stabilization. The patient subsequently underwent a T8-T12 posterior stabilization. Intra-operative histology samples confirmed non-Hodgkin's lymphoma. The patients pre and post-operative ASIA score was T7 AIS D. This patient underwent a post-operative CT scan demonstrated below.

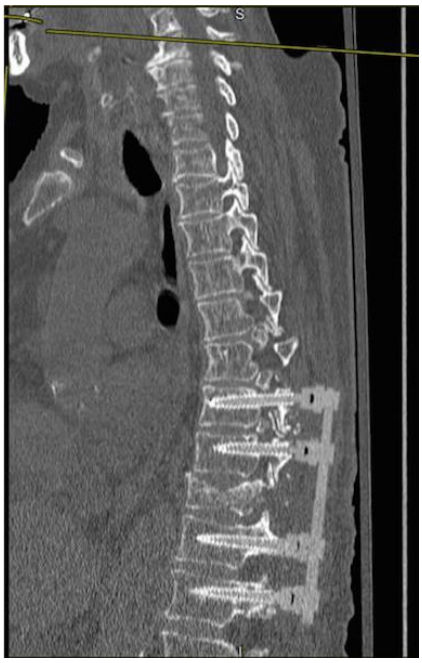

Image 3: Post-operative CT scan demonstrating T8-12 fusion. (There is limited artefact present. The patient passed away in December 2020, 6 months following her surgery.)

Results

Due to medical oncological advancements the surgical treatment of metastatic spinal disease is becoming an increasing area of focus for spinal surgeons. Patients are living longer with metastatic disease. As a result, the optimal treatment for this cohort is being explored further.

Increasing numbers of patients are physically well enough to undergo surgical intervention. Surgical fixation involves stabilization with metal implants. These implants have several disadvantages related to administration and delivery of adjuvant radiotherapy. Carbon fibre aims to overcome these disadvantages.

Due to the limited availability of health resources, consideration should be given to which patients will benefit the most from these implants. Another point that warrants consideration is where will the funding for the more expensive implants come from. If this is considered a specific assistant to oncologic management, these implants should possibly be funded through oncology funding streams, rather than surgical funding streams.

We recommend further larger follow up studies to assess the efficacy of carbon fibre implants in the surgical treatment of metastatic spinal disease.

Discussion

The purpose of spinal stabilization surgery and decompression in metastatic disease is to improve the quality of life for patient's living with a diagnosis of malignancy. Untreated, intractable pain and profound neurologic deficit may significantly worsen the quality of life for a patient who may have an otherwise good short to mid-term prognosis.

Metastatic tumors account for 97% of spinal tumors[1]. The most common underlying malignancies to metastasize to the spine are breast, prostate, renal, lung and thyroid[2]. As many as 70% of patients with cancer have spinal metastases and up to 10% will develop some degree of spinal cord compression[3]. This demonstrates the huge workload that spinal tumors represent.

The main treatment option for most spinal metastases is radiotherapy and particularly, external beam radiotherapy (EBRT) and brachytherapy[4]. Surgical intervention is recommended for spinal instability, spinal cord compression and those with radioresistant tumors[5].

Radiotherapy was the main stay of treatment of metastatic spinal disease up until 2005, when Patchell et al.[6] demonstrated that surgery combined with radiotherapy was greatly superior to radiotherapy in this cohort. Those who underwent surgical stabilization followed by radiotherapy were much more likely to be ambulatory compared to those who underwent radiotherapy alone. This revolutionized the treatment of those with metastatic spinal disease.

A wide range of surgical procedures can be undertaken, however most combine a decompression which relieves pressure on the spinal cord and stabilization to prevent collapse of the spine. Traditionally, stabilization was undertaken using titanium instrumentation sets.

However, there are several disadvantages to using titanium in this cohort. This led to the early use of carbon fibre in this group to overcome these disadvantages. The main advantages the use of carbon fibre has over traditional metal is their radiolucency and enhanced adjuvant radiotherapy.

This lack of artefact permits more accurate prescribing and administration of post-operative radiotherapy and allows visualization of potential post-operative complications such as hematomas or deep infections. Carbon fibre implant sets are radiolucent on traditional radiographs and barely visible on CT and MRI scans[7]. Furthermore, the absence of artefact also has potential benefits for adjuvant radiotherapy. There is minimal interference with post-operative radiotherapy, producing better outcomes. Adjuvant radiotherapy is valuable because of the difficulty in obtaining clear margins in many cases.

Potential benefits of carbon fibre implants are more effective delivery of post-operative radiotherapy.
The presence of metal artefacts on CT distorts the calculation of required radiotherapy potentially leading to under or over treating residual metastatic disease. There are also difficulties in delivering the prescribed dosage of radiotherapy, with a 5-10% decrease in dosage penetrating posterior to the metal rods as a result of attenuation[8]. This can lead to underdosing of residual tumors, thus, been ineffective. More concerning is the potential to over-dose tumors, which can lead to radiation myelopathy a feared complication of post-operative radiotherapy.

There can be a scattering effect when delivering radiotherapy to the residual lesion caused by the presence of high atomic number metals such as titanium, which can also lead to radiation myelopathy. Carbon fibre has a much lower carbon number equivocal to adjacent biological structures and as a result, there is less scattering effect.

One major disadvantage to using carbon fibre implant sets is the inability to contour the rods intra-operatively. This potentially may make the implants more unsuitable to longer fusions or those that cross transitional zones. Another disadvantage of carbon fibre is that it may not enjoy the same mechanical properties of metallic implants, and therefore be prone to earlier failure. This risk must be weighed against the potential advantages of is use, as described above. Carbon fibre implants are also significantly more expensive than titanium. The economic considerations for their use need to be justified. In that sense, the opinion of radiation oncologist is typically sought before using carbon fibre, to ensure there is a practical value.

The cost of a set consisting of eight screws and two rods, which in an isolated metastatic deposit represents fixation two levels above and below the affected segment. The cost of a carbon fibre set is approximately 9000 euro compared to approximately 3500 euro for a titanium set.

Furthermore, in an era with a strong focus on health economics, there is strong evidence that surgical stabilization followed by radiotherapy is cost effective in terms of cost per extra day of ambulation and cost per life year gained compared to radiotherapy alone.[9]

Declaration of Conflicts of Interest:
The authors have no conflicts of interest to declare.

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