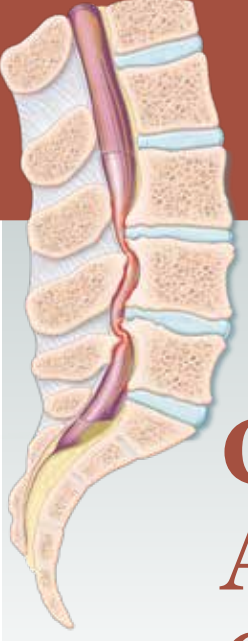

Cervical Disc Arthroplasty: A Movement-Sparing Surgical Option in Cervical Disc Degeneration

ABSTRACT

Degeneration of the cervical discs is a common problem and can cause compression of cervical nerve roots and/or the spinal cord. This in turn may lead to permanent neurological injury, disability and socioeconomical impact for the patient. Surgical management typically includes either an Anterior Cervical Decompression and Fusion (ACDF) or a Posterior Decompression with or without fusion or laminoplasty. Over the past 20 years, Cervical Disc Arthroplasty (CDA) has been an increasingly viable alternative to the "Gold Standard" ACDF, after failure of conservative management in the appropriately selected patient. Single and multi-level CDA has a growing body of evidence to support its equivalency - and even superiority - to ACDF in long-term clinical outcomes.

KEYWORDS: Cervical degenerative disc disease; Cervical Disc Replacement; Cervical Disc Arthroplasty; Radiculopathy; Myelopathy

CME Pre-test Quiz

Introduction

Cervical disc degeneration is a frequent problem, predominantly impacting the aging demographic. The degenerative process, affecting both symptomatic and asymptomatic individuals, underscores the complexity of the aging cervical spine. While conservative management remains the cornerstone for axial neck pain, symptoms due to impingement on neurological structures may require surgical intervention. Among the evolving array of surgical options, Cervical Disc Arthroplasty (CDA) has gained prominence, offering a motion-spar-

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ing alternative to the traditional Anterior Cervical Discectomy and Fusion (ACDF). This article discusses the pathogenesis and sequalae of cervical disc degeneration, explores the history of CDA, delineates the criteria for surgical candidacy, and reviews the evidence supporting its efficacy.

Cervical Disc Degeneration

Degeneration of the cervical discs is an inevitable progression affecting the aging population. The degenerative process begins with dysfunction such as annular tears, progresses to instability with disc herniation and/or resorption of the nucleus pulposus, which can then lead to restabilisation with bone hypertrophy and ankylosis.[1] Degenerative changes occur in both symptomatic and asymptomatic individuals. Surgery on the cervical spine may be required when the degenerative process leads to symptomatic impingement of either the cervical spinal cord and/or the exiting nerve roots. The mid to lower cervical discs have a greater range of motion and so are predisposed to earlier degeneration. C5/6 and C6/7 are the most common levels involved.

Patients can suffer predominantly central (axial) neck pain, mainly upper limb dominant (radicular) pain with lower motor findings in the arm, more widespread upper motor neuron (myelopathic) symptoms or a combination of all three. Unless there is mechanical instability or another pathological process such as a tumour or infection, surgery is rarely recommended for purely axial neck pain. Those complaints are best managed with an active physiotherapy program and medical/interventional pain management strategies. Surgery may be needed to decompress neurological structures directly by removing osteophytes, disc herniations, hypertrophied ligamentum flavum or facet joints or indirectly by increasing disc height to restore foraminal space or reduce ligamentum infolding. Maintaining stability after the surgical removal of structural components often requires an ACDF, a posterior instrumented fusion, a laminoplasty (the preservation and reattachment of the laminae and spinous processes) or a cervical disc arthroplasty.

Cervical radiculopathy produces upper extremity symptoms associated with one or more nerve roots (Table 1). Symptoms include pain, paraesthesia and motor weakness in a predictable dermatomal/myotomal pattern. The suitable surgical candidate exhibits a pattern of radicular symptoms compatible with the nerve root seen to be compressed on MRI imaging.

Cervical myelopathy is the presence of upper motor neuron symp-

Table 1: Simplified Cervical Nerve Root Assessment Chart

Nerve Root	Motor Function	Dermatome Region	Deep Tendon Reflex
C4	Shoulder elevation	Trapezius	
C5	Shoulder abduction	Lateral shoulder	
C6	Elbow flexion	Lateral upper arm to thumb	Biceps
C7	Elbow extension	Posterior upper arm to 3rd digit	Triceps
C8	Thumb extension	Ulnar forearm to 5th digit	
T1	Finger abduction	Axilla to mid forearm	

toms produced by compression of the spinal cord. Compression from a degenerative process is referred to as Degenerative Cervical Myelopathy (DCM). DCM symptoms include upper extremity weakness, hand numbness and clumsiness, fine motor dysfunction and gait abnormalities. Examination findings may include increased tone (spasticity and hyper-reflexia), a positive Hoffmann's reflex, an inverted radial reflex and sustained clonus. Extreme spinal cord compression can lead to bowel/bladder dysfunction and progressive quadriplegia. DCM severity is classified using the Modified Japanese Orthopaedic Association (mJOA) score (Table 2). The mJOA scale also correlates with outcomes; the lower the score pre-operatively (greater cord dysfunction), the less improvement is seen post-operative.

Progressive cervical radiculopathy or DCM that have failed to improve with conservative treatment usually require surgical intervention. The options include anterior approaches, (anterior discectomy followed by fusion or disc replacement), or posterior surgery, (laminectomy with or without fusion or laminoplasty). This paper focuses on CDA compared with ACDF.

History of Disc Arthoplasty

Ulf Fernstrom is credited with implanting the first artificial cervical device in 1966.[2] The implant was a stainless-steel ball bearing that, unfortunately, had a very high rate of subsidence, migration and instability.[3] The catastrophic outcomes ensured that ACDF remained the standard of care for anterior cervical spine surgery. But the search for a functional disc replacement continued. One of the first modern prototypes was designed by B.H Cummins in 1989 at Frenchay Hospital in Bristol, UK.[4] It was a two-piece, metal on metal, stainless steel ball and socket design with anchoring screws. Unfortunately screw migration dysphagia were common complications.[5] In the

Table 2: Modified Japanese Orthopaedic Association Severity score for DCM

Category	Score	Description
Upper Extremity Function	0	Unable to move hands
	1	Unable to eat with a spoon but able to move hands
	2	Unable to button a shirt but able to eat with a spoon
	3	Able to button a shirt with great difficulty
	4	Able to button a shirt with mild difficulty OR fine motor dysfunction such as frequent dropping of objects, clasping jewellery or marked handwriting changes.
	5	Normal hand coordination
Lower Extremity Function	0	Complete loss of movement and sensation
	1	Complete loss of movement, some sensation present
	2	Inability to walk but some movement
	3	Able to walk on flat ground with walking aid
	4	Able to walk without walking aid, but must hold a handrail on stairs
	5	Moderate to severe walking imbalance but able to perform stairs without holding handrail
	6	Mild imbalance when standing or walking
	7	Normal walking
Upper Extremity Sensation	0	Complete loss of hand sensation
	1	Severe loss of hand sensation or pain
	2	Mild loss of hand sensation
	3	Normal hand sensation
Sphincter Function	0	Inability to urinate voluntarily (requires catheterisation)
	1	Frequent urinary incontinence
	2	Urinary urgency or occasional stress incontinence
	3	Normal urinary function

1990s and 2000s, a renewed interest in cervical disc arthroplasty led to a plethora of new implant designs and finally success. Currently there are a significant number of devices for single and two-level disc replacement approved by the US Food and Drug Administration on the market (Table 3). The implant designs vary by fixation method, (keel, screw fixation, hydroxyapatite coated end plates for bony ingrowth), by core type, (fixed or mobile), by articulating materials, (metal on polyethylene versus metal on metal) and the presence or absence of a prosthetic annulus to constrain movement. These differences lead to variations in the surgical method of site preparation, implant insertion and implant stiffness. Theoretically, matching the stiffness of the implanted construct to the mobility of the patient's spine should contribute to implant success or failure. If the implant is too rigid, the prosthetic disc will not move, leading to either loosening at the disc-bone interface or unintended fusion of the disc space. If the implant is too mobile, this may lead to instability and hyperlordosis/kyphosis of the implant (Figure 1).

Table 3: Commonly used US FDA-Approved Disc Replacement Products

Single Level	Single and Two-Level
Synthes ProDisc C Vivo	ZimVie LDR Mobi-C
OrthoFix M6-C	Medtronic Prestige LP
Globus Secure C	NuVasive Simplify

Who is a Candidate for Disc Arthroplasty?

CDA is increasing in popularity in Europe and North America to treat the upper extremity radicular symptoms of disc herniations or foraminal stenosis.

Disc replacement addresses these symptoms either directly, by decompressing the nerve root with the removal of the herniated nucleus pulposes or disc-osteophyte complex, or indirectly by inserting the arthroplasty to restore foraminal height. Typically, the surgery is limited to one or two contiguous levels.

Classic indications include:

- intractable radiculopathy caused by disc or bony impingement
- failure of more than 6 weeks of conservative care
- one or two contiguous symptomatic levels, from C3 to C7
- a skeletally mature patient

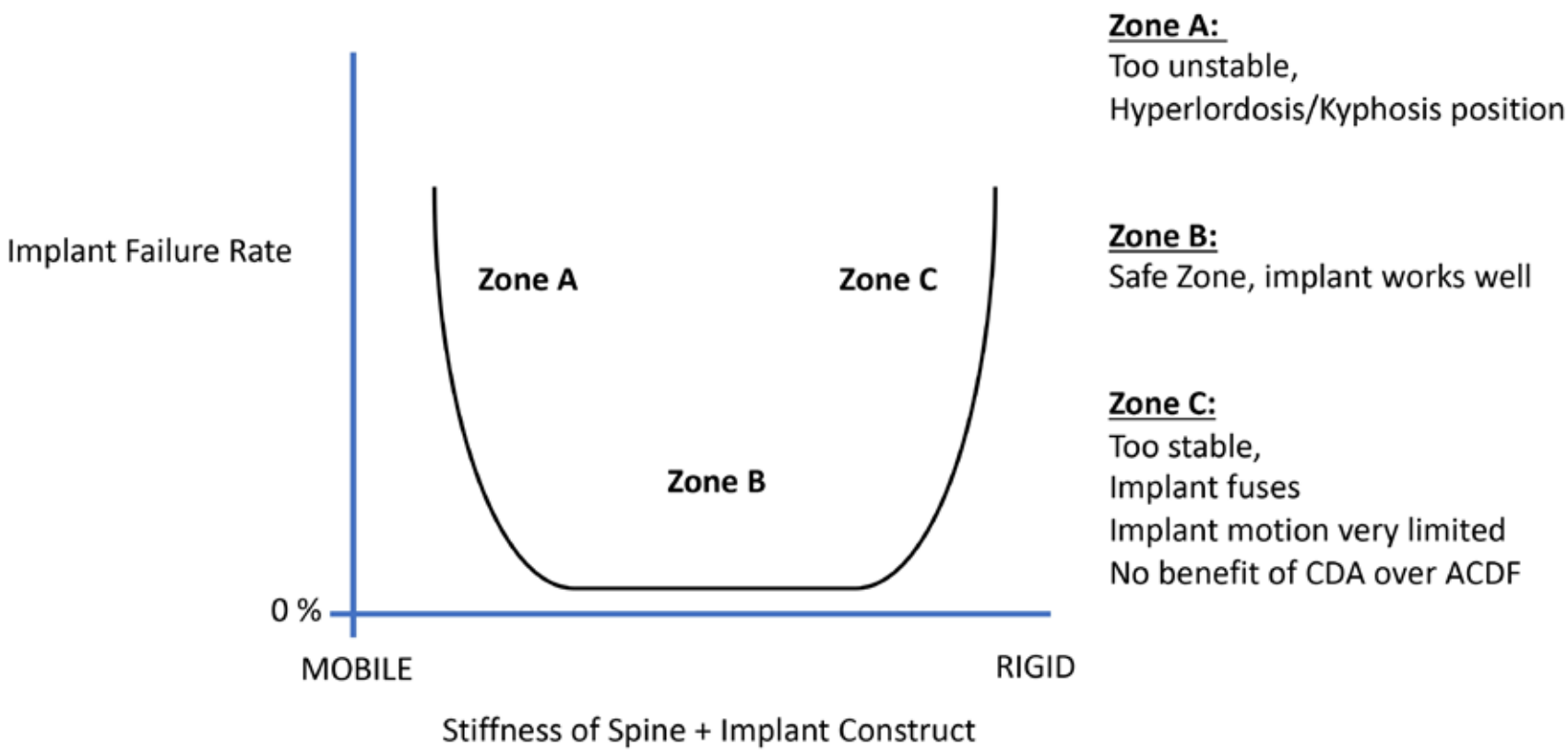
Disc arthroplasty is contraindicated in the following situations:

- cervical instability
- osteoporosis or osteopenia defined as DEXA BMD T-score less than -1.5
- acute or chronic infection, systemic or at the operative site
- cervical deformity or disease (e.g., ankylosing spondylitis, rheumatoid arthritis)

- known allergy or sensitivity to implant materials (cobalt, chromium, molybdenum, titanium, hydroxyapatite, or polyethylene)
- severe facet joint degeneration

The role of disc arthroplasty to treat spinal cord compression causing myelopathic symptoms is debatable.[6] Traditional techniques have focused on protecting the spinal cord through decompression and fusion to increase space and prevent motion at the surgical levels. By allowing movement, disc arthroplasty is a paradigm shift in managing DCM. If the surgeon can adequately decompress the spinal cord operating only through the disc space and does not need to remove an entire vertebral body, then disc replacement seems a viable option. Motion restriction is not required to prevent further cord injury as long as the spinal canal volume is adequate and movement does not itself cause dynamic compression. Another concern in using disc arthroplasty is the impact of the implant on post-operative MRI imaging. Metallic cervical disc arthroplasties can cause significant image distortion. For those post-operative patients with incomplete recovery, MRI scans are usually required to ensure there is no ongoing spinal cord compression and to identify the presence of increased T2 weighted signal intensity in the cord at the compression site.[7,8] The artificial disc can prevent this assessment. Metal suppression sequences may improve the quality of the MRI image and some implants contain more metal than others.[9]

Figure 1: Cervical Disc Replacement and Theoretical Failure Mechanism



Case Example

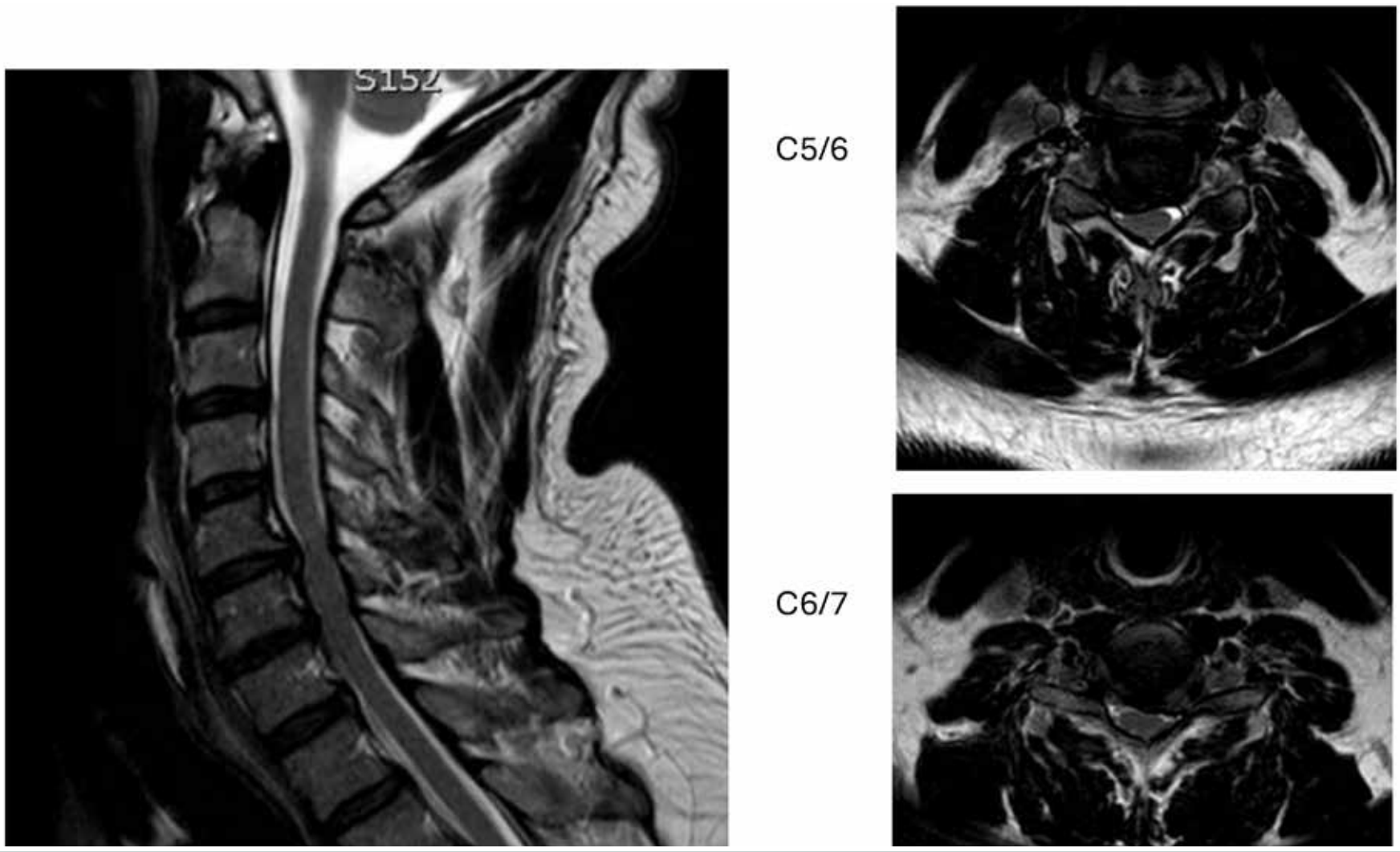
A 50-year-old man presents with bilateral upper extremity radiculopathy indicative of C6 and C7 nerve root compression. He has received a thorough course of conservative treatment including physiotherapy, pharmacotherapy and interventional pain management strategies without adequate pain relief and his symptoms continued to severely limit his daily activities. Images of the cervical spine MRI show foraminal compression of the right C6 and bilateral C7 nerve roots (Figure 2). Disc height is slightly reduced. The patient received C5/6 and C6/7 cervical disc arthroplasties. (Mobi-C, ZimVie Inc., USA). Intra-operative fluoroscopic images (Figure 3) and 6-month post-operative x-rays (Figure 4) show excellent implant placement. The patient started physiotherapy 2 weeks post-operative and had full relief of his upper extremity symptoms. Improvement continued beyond his 6-month follow up.

Evidence Based Overview

Conceptually, replacing a cervical disc to maintain motion, rather than fusing the motion segment, should ease the "wear and tear" on the neighboring discs. Diminishing stress on the adjacent levels while preserving motion at the target site should reduce the need for future surgery. But what about the data?

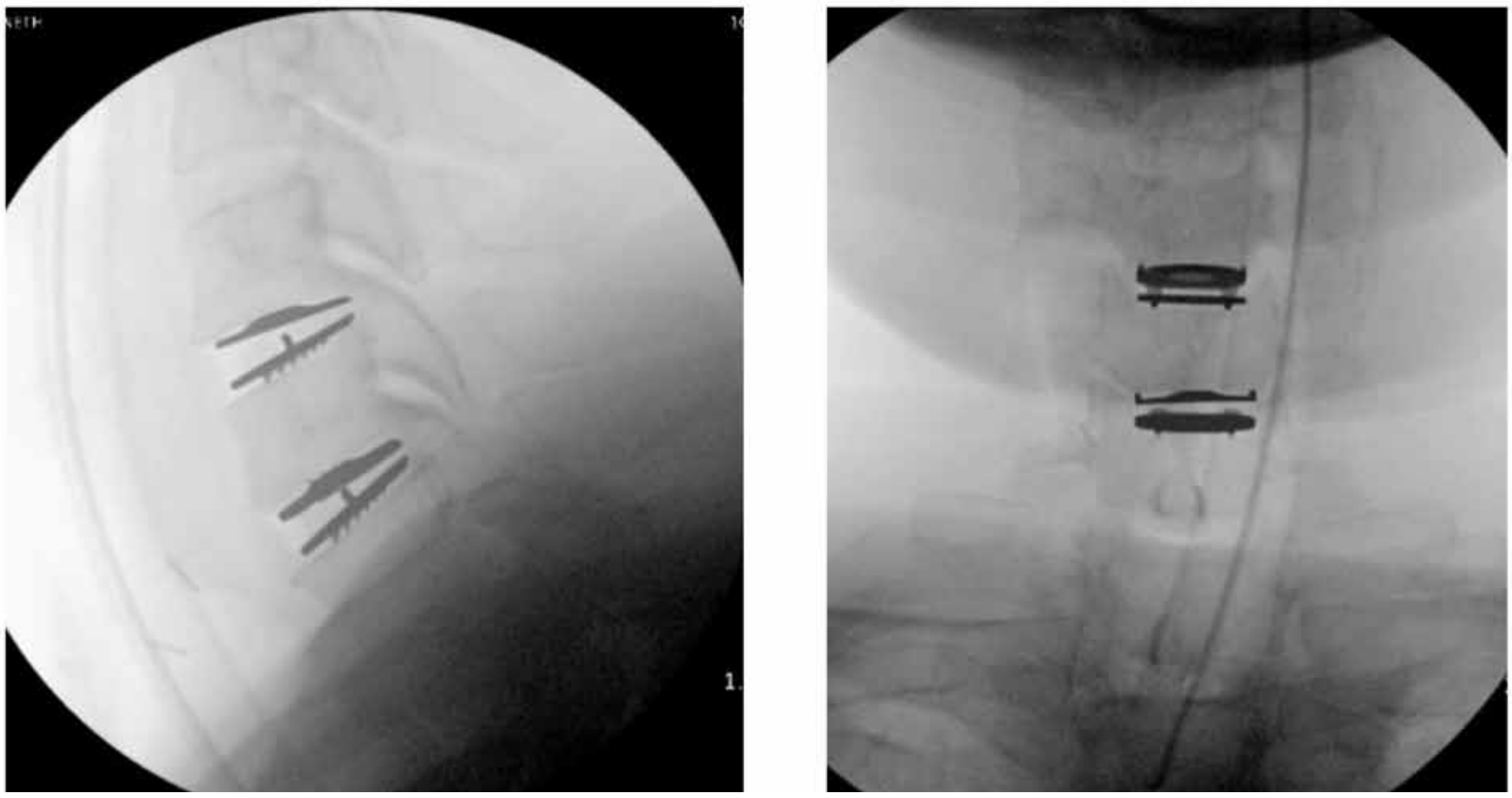
The rate of adjacent level surgery varies widely throughout the

Figure 2: MRI Cervical spine, T2-weighted sagittal and axial sequences



literature. Wang *et al.* showed that the rate of adjacent level surgery following a single level ACDF is 6.2% at 8 years.[10] Similar data were found by Scheurmans *et al.* (6.8%) but higher rates were identified at 10 year follow up by Chung *et al.* (13.2%).[11,12] In theory, disc replacement should lead to a lower rate of adjacent level surgeries. A meta-analysis of minimum 48-month follow up data comparing ACDF to CDA by Deng *et al.* showed the overall rate of symptomatic adjacent-level disease requiring surgery in the cervical disc replacement group was significantly lower than in the anterior cervical fusion group.[13] However, sub-group analysis favoured an unrestricted prosthetic design. The revision surgery rate for the semi-restricted prostheses showed no statistical difference compared to ACDF. This analysis highlights the importance of implant design and the apparent need to recreate normal cervical spine kinematics in disc replacement technology.[14] The data appear even stronger in favour of CDA when assessing two-level interventions. In reviewing the five-year US FDA clinical trial data for the Mobi-C prosthesis, Radcliff *et al.* concluded that "both cervical total disc replacement and ACDF significantly improved general and disease-specific measures compared with baseline. However, there was significantly greater

Figure 3: Intra-operative fluoroscopic images



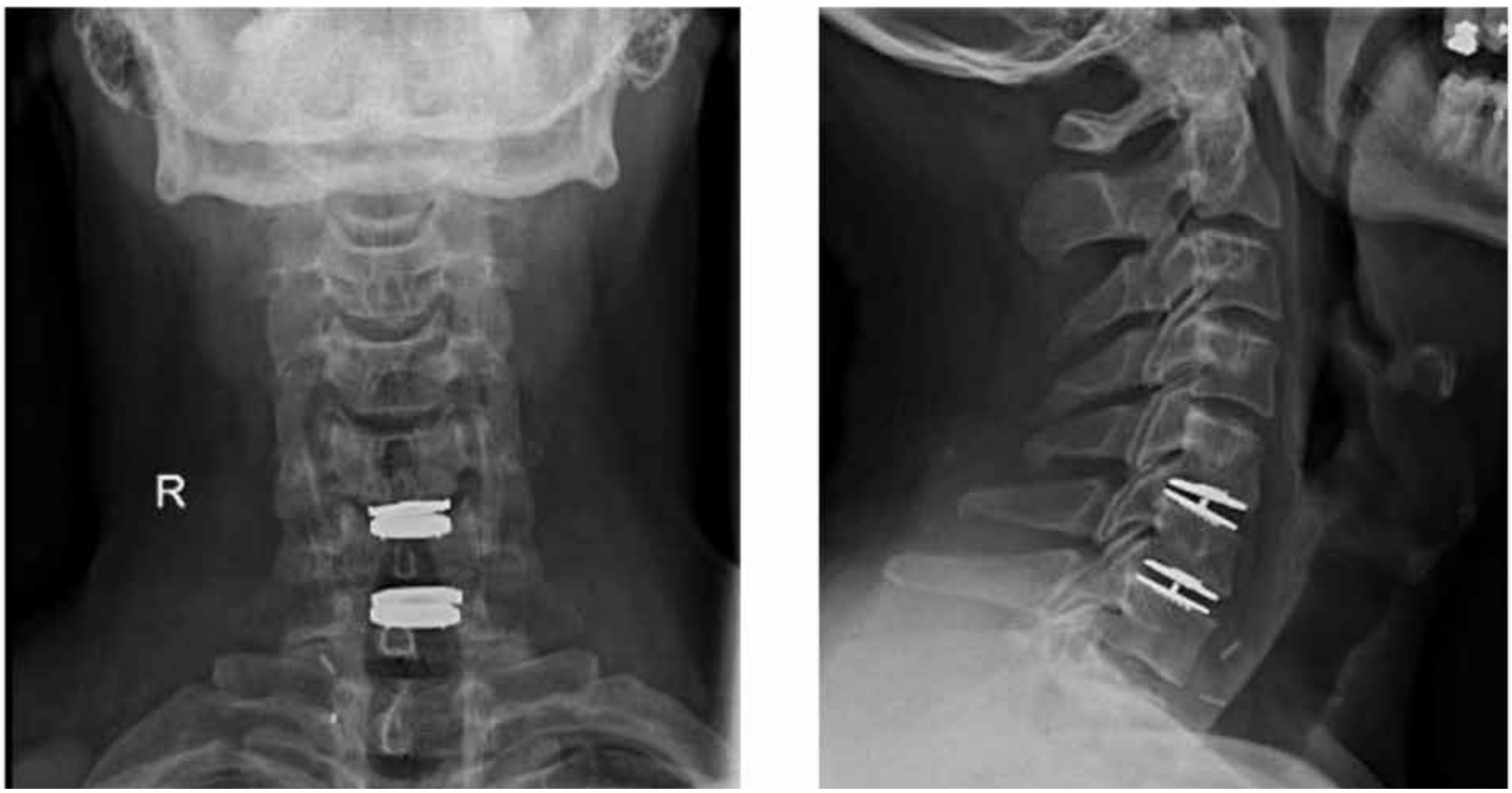
improvement in general and disease-specific outcome measures and a lower rate of reoperation in the 2-level disc replacement patients versus ACDF control patients".[15] These benefits appeared to extend to the 10-year follow-up.[16] Similar reported benefits in clinical outcomes and equal or better re-operation rates compared to ACDF have been shown with other CDA implants including the M6-C (Orthofix, Lewisville, Texas), the ProDisc-C (Centinel Spine, West Chester, Pennsylvania) and the Secure-C (Globus Medical, Audubon, Pennsylvania).[17-19] Overall, the clinical and economic data support the use of CDA and in 2019, Health Quality Ontario, the provincial advisor on quality in health care recommended the public funding of CDA under a quality-based procedure model for hospitals in Ontario.[20]

Conclusion

Cervical disc degeneration poses a significant challenge in the aging population. While axial neck pain can often be managed conservatively, the impingement of neurological structures necessitates careful consideration of surgical options.

Compared to ACDF, disc replacement emerges as a promising solution for addressing the neurological sequelae. The intricate interplay of implant design, fixation methods, and core types demands a nuanced approach in

Figure 4: Post-operative XRs



At the 6 month follow-up the patient had no neck or arm pain and had retuned to full, unrestricted activities.

selecting the most suitable implant for specific patients. The evidence underscores the potential advantages of disc arthroplasty, with studies indicating lower rates of adjacent-level surgeries and improved outcomes, especially in two-level interventions. Careful consideration of indications and contraindications for disc arthroplasty ensures the procedure's appropriateness for each patient. CDA stands as a viable and increasingly popular option for addressing the neurological manifestations of cervical disc degeneration.

SUMMARY OF KEY POINTS

Cervical radiculopathy symptoms include pain, paresthesia, numbness, and weakness in a recognised dermatomal and myotomal pattern.

First-line conservative treatment for cervical radiculopathy includes physiotherapy, analgesia, and non-steroidal anti-inflammatories.

Cervical disc replacement is an evidence-supported intervention for upper extremity radiculopathy that has failed conservative treatment.

Many designs of cervical disc arthroplasty are currently available for implantation in North America.

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CLINICAL PEARLS

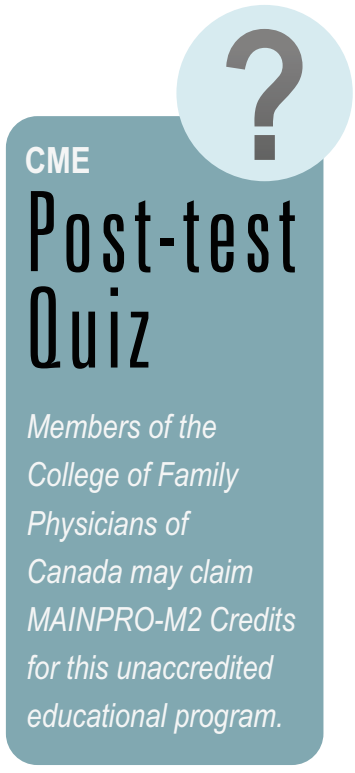
Cervical degenerative disc disease is a common radiographic finding present in both the symptomatic and asymptomatic population.

Axial neck pain, in the absence of red flag symptoms is best managed with an active physiotherapy program and pain management strategies.

Cervical disc arthroplasty is an evidence-supported surgical option to address central or foraminal cervical stenosis at the disc level.

1 or 2-level cervical disc arthroplasty has a lower re-operation rate than anterior cervical decompression and fusion.

Cervical disc arthroplasty procedure can be performed through a 4cm incision in the front of the neck.



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