

Cervical Arthroplasty for the Treatment of Cervical Spine Disease

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Abstract

Cervical arthroplasty involves replacement of the intervertebral disc space with a prosthetic device designed to maintain motion. The interest in cervical arthroplasty has increased of late because of the perceived shortcomings of cervical fusion surgery. The Bryan® cervical disc prosthesis is the only currently available cervical disc prosthesis. Over the past four years, over 5,500 implants have been surgically placed in patients who predominantly had neural compression. The use of arthroplasty for the management of neck pain is being examined. The long-term implications of arthroplasty are not known but in the short-term hospital stays are short, motion is maintained, hip graft complications are avoided and a cervical collar is not required. The real issues relate to longevity of the implants, wear and particle debris, and potential protection of adjacent segments from degeneration. It will take at least 10 years of careful follow-up before the answers to these questions are derived.

Introduction

Surgery for spinal disorders has been performed for over 50 years. Traditionally, the indications for spinal surgery for degenerative disease have been for neural compression. Simple laminectomy has been complemented by anterior procedures where total discectomy is performed. A variety of procedures are performed after this, including no placement of implants, or more commonly intervertebral bone grafting and sometimes plating. Surgery for primary axial neck pain is less well defined. Cord compression due to spondylotic disease termed cervical spondylitic myelopathy (CSM), and acute disc herniation, are common spinal disorder with controversy over the role and timing of surgical intervention as well as the optimal treatment.^{1-3,6-9,15,19,20} Over the past 50 years, vari-

ous combinations of anterior and posterior instrumented surgeries have been devised and refined and continue to be utilized. In the absence of arthrodesis, kyphotic deformity is always a feared complication.^{5,17} The problem with interbody or posterior cervical fusion is that typically a reduction in effective motion occurs and there are significant morbidities associated with bone graft harvest.¹⁶ Coupled with this, the incidence of adjacent segment deterioration, requiring reoperation, has been quoted as being as high as 3% per year.¹⁴ Consequently, there has been a more recent emphasis on surgical techniques such as cervical laminoplasty or cervical disc arthroplasty to maintain motion, avoid deformity, reduce adjacent segment stresses, and allow for an adequate decompression without having to use bone graft. The precise indications for arthroplasty are currently being explored and the biomechanics and changes with disease assessed.

History

Spinal arthroplasty has a relatively short history. The aims of the ideal intervertebral disc prosthesis have included preservation of normal motion, ease of implantation, ease of revision, minimal wear, longevity, ease of revision and ease of postoperative imaging. All these goals have been achieved in a variety of permutations over the past 40 years. Despite the ease of access in the cervical spine, spinal disc replacement surgery has historically concentrated on the lumbar spine.^{7,8,10} Fernstrom¹¹ in 1966 introduced an intracorporal endoprosthesis that consisted of a stainless steel ball inserted into the centre of a lumbar disc after laminectomy. Although Fernstrom focused on lumbar discs prostheses, he also placed these prostheses in the cervical spine. Cummins more recently has described his experience with the Cummins artificial cervical joint.⁷ This prosthesis was basically a stainless



Figure 1. The Bryan disc prosthesis showing the milled endplates that allow for an interference fit of the prosthesis

steel ball-and-socket joint. A major shortcoming of this design has been the inability to instrument more than one level. They described implantation of 22 devices, designed within their unit, in 20 patients. Two patients were lost to follow up. Of the 18 remaining patients, x-rays demonstrated no movement at the level of implantation in two patients. This rate of failure to preserve normal motion can be considered unacceptably high. Wigfield *et al*³ modified the Frenchay joint to allow more physiological motion. They published a pilot study in 2002 in which the device was implanted in 15 patients. The study demonstrated that implantation of the device is safe, and that motion is well preserved with the modified device in the short term. Follow up reports still support these conclusions.²⁴ Pointillart described a prosthesis in 2001 that allowed motion between a titanium based prosthesis with a carbon surface that articulated with the inferior endplate of the vertebra above the prosthesis.¹⁸ However eight of ten patients fused within two years. New prostheses are expected to become available over the next few years.

The Bryan® cervical disc prosthesis (Medtronic-Sofamor Danek, Memphis, TN, see Fig. 1) was first reported as being used for the management of cervical spondylotic disease in 2002 by Goffin *et al*² and subsequently by Sekhon.²² This cervical disc prosthesis consists of a polyurethane nucleus

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designed to fit between two titanium alloy shells. Each shell has an outer titanium porous coating to encourage bony ingrowth and long-term stability. A polyurethane sheath surrounds the nucleus and is attached to the shells with titanium wire, forming a closed compartment. Sterile saline is placed into the prosthesis and titanium alloy seal plugs provide for its retention. This prosthesis requires precise milling for its placement and the technique aims at meticulous centering of the prosthesis. Multiple levels can be instrumented but must be visualized on fluoroscopy. Goffin *et al*¹² described the use of cervical arthroplasty in an attempt to maintain cervical motion and avoid arthrodesis after decompression. In their study, 60 patients underwent single level anterior cervical decompression and placement of an artificial disc prosthesis. Of note is that 93% of Goffin's patients had radiculopathy predominantly. They reported follow up at 12 months, with clinical success reported at between 85% and 90%. No subsidence of the devices was noted and possibly two patients had device migration. No spondylotic bridging occurred at the implanted disc space. Range of motion was preserved and no device had been explanted or surgically revised. They have subsequently reported on three-year results in this group and a similar one-year follow up on bi-level replacements, with equally acceptable results.¹³

Indications

The commonest indication for cervical arthroplasty is as an intervertebral disc replacement after total discectomy is performed. A typical case is shown in Figs. 2a and 2b. Acute disc herniations need to be distinguished from cervical spondylotic disease. Over time, the large and varied range of motion of this region places stresses on the cervical spine, resulting in inevitable degenerative changes, including desiccation of the discs, disc bulging, facet joint hypertrophy, narrowing of facet joints, and hypertrophy of ligaments. This process, ubiquitous in the adult population, is known as cervical spondylosis. The above changes may result in narrowing of the spinal canal or of the intervertebral foramen (or both) and

subsequently compression of the spinal cord or cervical nerve roots respectively may ensue. Acute cervical disc herniation, unlike spondylotic disease, tends to affect a younger population group. They may be associated with trauma, particularly with acute hyperflexion, rotation, or both. The annulus fibrosus and posterior longitudinal ligament may tear, allowing part of the nucleus pulposus to herniate into the spinal canal or intervertebral foramen. Again either the cervical spinal cord and/or the cervical nerve roots may be involved. However, unlike the case with spondylosis, it is the nerve roots that are most commonly affected. Frequently an acute disc herniation may be superimposed upon existing spondylitic change to cause a clinical problem.

Cervical nerve root compression typically results in neck pain and arm pain in a radicular distribution. The most commonly affected cervical nerve roots are C6 and C7. Paraesthesia may accompany the pain and these are typically dermatomal in distribution. Associated sensory loss, typically to pain and temperature, again in a dermatomal distribution, is not uncommon. Weakness and hyporeflexia (that is, lower motor neuron weakness) may also be present. The onset of these symptoms may be sudden or insidious and progressive. A chronic episodic presentation is more commonly caused by spondylitic change; however, an acute onset can imply either an acute disc herniation or spondylitic change. The presence or absence of trauma can be an important differentiating factor.

Cervical cord compression due to degenerative disease can present with a variety of syndromes. Most commonly patients describe stiffness in the upper and lower limbs and difficulty with fine movements in the hands. Examination generally reveals weak-

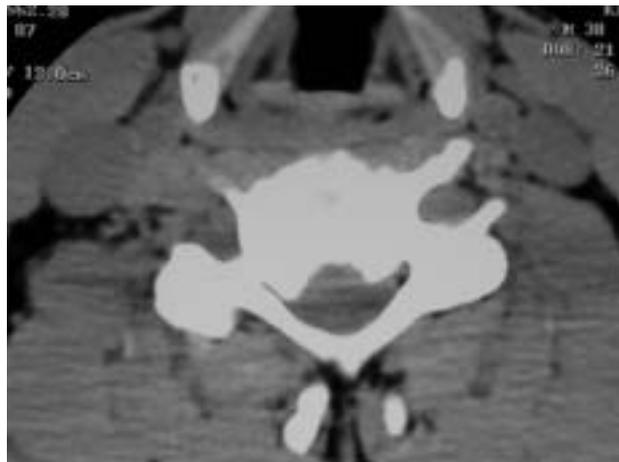


Figure 2. Preoperative (a) axial CT and (b) sagittal MR scans of the cervical spine showing typically spondylotic or disc bulges causing neural compression in a patient ideal for cervical arthroplasty



ness below the level of compression, with hypertonicity and exaggerated deep tendon reflexes including an extensor plantar response. Sensory changes tend to be less marked. Other spinal cord syndromes which may be associated with cervical cord compression include central cord syndrome, Brown-Sequard syndrome and anterior spinal artery syndrome. Typically with acute cervical disc herniation these syndromes will develop rapidly. An episodic and insidious onset implies spondylosis as the cause. Cord compression and myelopathy or root compression and radiculopathy can occur concurrently in either acute cervical disc herniation or cervical spondylosis.

When looking at axial neck pain, the selection of patients becomes more

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difficult. Arthroplasty is not suitable for patients who have neck pain where the cause is thought to be myofascial disease, facet degeneration, or deformity. Neck pain related to degenerative disc disease is the only aetiology potentially treated with this intervention. Sekhon reported in seven patients that, if surgery was performed for cervical decompression of the spinal cord, neck pain often improved.²¹ All these patients had surgery for neural compression and the improvement in neck pain was an incidental finding. In patients with neck pain as their primary symptom, selection is the key. CT scanning, static and dynamic fluoroscopy, MR scanning, and possibly multilevel provocative discography are all used to try and localize at least one painful disc segment. However, aside from exclusion, there is no clear diagnostic test. SPECT scanning with CT does not appear to have the same sensitivity in the cervical spine as it does in the lumbar spine and subtle spondylotic disease in facet joints does not appear to be as readily defined on CT. Subtle deformity plays a greater role in potential complications after surgery than in the lumbar spine and, with current designs, particularly in the case of unconstrained devices such as the Bryan® prosthesis, surgery is best avoided if kyphosis is present. Studies are currently underway to evaluate primary axial neck pain and its potential correction with arthroplasty but at the moment ideal candidates are those with a single degenerative disc on MR scanning, negative cortisone facet injections, negative bone SPECT scans, minimal posterior element facet spondylotic disease on CT, normal cervical lordosis or a straight cervical spine and motion on dynamic films with no evidence of instability. The role of discography is unclear.

Investigations

Plain x-rays, CT, MR, and bone scanning all play a role in the work-up of patients for potential cervical arthroplasty. Plain x-ray is often the first investigation utilised by clinicians. Particular features of interest in this setting are the overall balance of the cervical spine, deformity, if any, and any potential instability on dynamic

films. Coupled with this, motion must be demonstrated at any levels where arthroplasty is contemplated. Aside from lack of motion or instability, other contraindications to cervical arthroplasty include active infection, an inability to visualize the disc space on lateral x-ray, osteoporosis, or ossification of the posterior longitudinal ligament (OPLL).

Computed tomography is also a useful investigation, primarily as it allows for accurate pre-operative planning of prosthetic size. The Bryan® disc ranges in size from 14 mm to 18 mm and occasionally in small individuals the smallest prosthesis available is too large and arthroplasty is not advisable. It is likely that smaller prostheses will be available in the future.

Surgical technique

The initial portion of surgery where cervical arthroplasty is performed is identical to that for an anterior cervical decompression and fusion. Implantation of the Bryan® disc uses a simple gravitational reference system to identify the centre of the disc space. A series of levels and plumb lines help determine the centre of the implantation site. This will change with future incarnations and different implants. The reciprocating vertebral bodies are milled to precision to match exactly the implants convex outer surface. Bony ingrowth occurs into the roughened outer surface over time. This tight fit provides stability to the endplate. The end result is shown in Fig. 3, with postoperative images shown in Fig. 4. The current procedure is very dependent on intraoperative fluoroscopy.

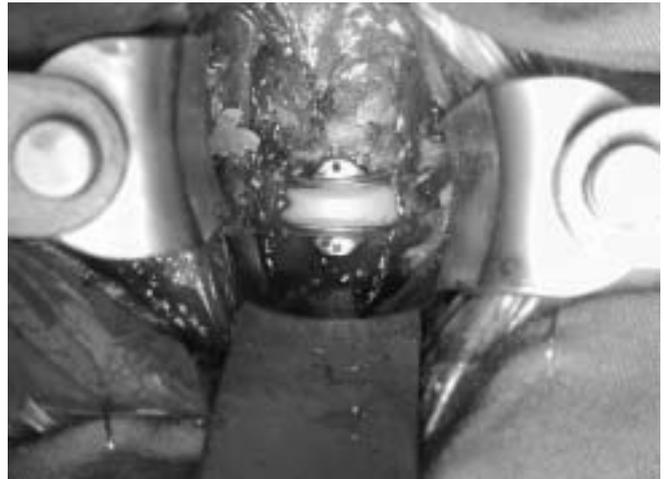


Figure 3. Intraoperative image of the Bryan disc prosthesis



Figure 4. Postoperative (a) lateral extension and (b) flexion films showing the normal motion at the level of the arthroplasty. The titanium shells but not the inner nucleus are visualized on this imaging.

Wear and particle debris

In a situation analogous to hip and knee arthroplasty, there have been concerns raised in terms of the longevity of cervical implants, potential particle and wear debris and the complications that may occur with these. Again, the Bryan® cervical disc prosthesis appears to be the most robust and most thoroughly tested. Anderson *et al* published their data last year on their biomechanics of the prosthesis and wear characteristics.⁴ Using cervical spine motion simulators, they reported minimal wear at 10 million cycles of motion, with 500,000 – 1,000,000 cycles being deemed equivalent to one year of normal cervical motion. Animal studies showed the polyethylene insert led to wear particles of a smaller size than that seen after hip and knee arthroplasty, but in the absence of an inflammatory reaction. No osteolysis was seen and they felt that the wear

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characteristics were acceptable. No one knows how long the Bryan® disc prosthesis will last. Estimates suggest survivals of at least 10 years but possibly as high as 20-40 years, quite different to those seen after large synovial joint surgery. To date no implant has been removed because of device failure and particle debris seems only to be of theoretical concern.

The future

It is possible, that the current prostheses available will not be the same used in 5-10 years. Refinements in techniques, clarification of indications, as well as improvements in biomaterials, should be realised over the next 10-20 years. The true incidences of adjacent segment disease need to be further realised and at some stage in the future, facet joint replacement may also be possible.

Conclusions

Cervical arthroplasty has arrived, yet caution needs to be exercised in its use. The ideal patient has a soft disc herniation with normal lordosis. The limitations and indications are currently being defined. Long-term data are still needed. As newer prostheses become available and more data are made available on the results of current designs, we will become more adequately equipped to use a powerful new tool in the management of cervical spine disease.

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