Abstract
Anterior cervical disectomy and fusion (ACDF) has been used to treat degenerative cervical spine diseases for almost six decades. In this literature review, we have summarised the history, indications, outcome and complications of the procedure. We also provide technical details on surgery. Despite the emerging new technical advances such as cervical arthroplasty, evidence continues to support the use of ACDF, given its well-established safety profile and effectiveness.

Introduction
Anterior cervical disectomy and fusion (ACDF) has been one of the most commonly performed procedures for degenerative spinal diseases, with more than five million operations conducted in the United States between 1990 and 1999.1 The main indications are for the treatment of cervical myelopathy and radiculopathy secondary to cervical disc prolapse and osteophyte compression. It has also been used to treat a range of other cervical diseases (mainly between C3 and T1 vertebrae) related to cervical instability (degenerative, traumatic, oncological, infectious, inflammatory, iatrogenic).2

History of the procedure
Prior to 1950, cervical spine surgery was primarily performed via a posterior approach.3 The anterior cervical approach was initially described in the 1950s to access the oesophagus.4 In 1958, Smith and Robinson5 applied the approach to cervical disectomy and interbody fusion using a horseshoe-shaped graft, harvested from the iliac crest. In addition, Cloward’s approach also removed osteophytes, leaving the PLL intact. The majority of the 47 cases (all of which had neck, shoulder and/or upper arm pain) reported complete relief. Other types of grafting e.g. the onlay graft developed by Bailey and Badgley6 and the keystone graft developed by Simmons and Bhalla7 have not been widely adopted.

Diagnosis
Neck and shoulder pain is a common complaint in primary care, hence careful selection is required to identify patients with pathology that warrants ACDF. The age-adjusted incidence of cervical radiculopathy is 83 per 100,000 persons (less common than lumbar radiculopathy), with potential risk factors including female gender, white race, cigarette smoking, axial load bearing, and prior lumbar radiculopathy.8

A recent literature review9 found no high-quality study that had measured the incidence or prevalence of cervical spondylotic myelopathy but the prevalence of surgically treated cervical spondylotic myelopathy was estimated as 1.6 per 100,000 persons.

Radiculopathy
As each nerve root exits above the pedicle of its like-numbered vertebra, a herniated disc usually impinges on the nerve root exiting from the neural foramen at the level of herniation (e.g. C4/C5 disc herniation tends to affect root C5). A summary of cervical disc syndromes is given in Figure 1.10

<table>
<thead>
<tr>
<th>Level</th>
<th>Percentage of cervical discs/%</th>
<th>Compressed root</th>
<th>Reflex diminished</th>
<th>Motor weakness</th>
<th>Paraesthesia</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>C4/5</td>
<td>C5</td>
<td>Deltoid and pectoralis</td>
<td>Abduction &gt; 90 degrees; elbow flexion</td>
<td>Shoulder</td>
</tr>
<tr>
<td></td>
<td>C5/6</td>
<td>C6</td>
<td>Biceps and brachioradialis</td>
<td>Forearm flexion</td>
<td>Upper arm, thumb and radial forearm</td>
</tr>
<tr>
<td></td>
<td>C6/7</td>
<td>C7</td>
<td>Triceps</td>
<td>Forearm extension</td>
<td>Fingers 2 and 3, all fingertips</td>
</tr>
<tr>
<td></td>
<td>C7/T1</td>
<td>C8</td>
<td>Finger jerk (exaggerated)</td>
<td>Hand intrinsics</td>
<td>Fingers 4 and 5</td>
</tr>
</tbody>
</table>
compression usually causes dermatomal or myotomal pain, paraesthesia or numbness and a range of lower motor neuron (LMN) signs including muscle atrophy, fasciculations, weakness in a specified myotome, reduced reflexes, as well as sensory changes in a dermatomal distribution.

A few clinical tests have been described to aid diagnosis. Axial loading of the head while tilting the head towards the symptomatic side may reproduce the radicular symptoms (Spurling’s sign); whereas axial traction may alleviate them. Symptoms may also be relieved by shoulder abduction in a sitting patient. These clinical tests tend to be highly specific but not very sensitive.

Myelopathy

Myelopathy may be acute or chronic; complete or incomplete. There may or may not be a history of acute trauma. Degenerative cervical myelopathy (DCM), defined as symptomatic myelopathy associated with degenerative arthropathic changes in the spine axis is a leading cause of acquired spinal cord compromise. Commonly there are signs of upper motor neuron (UMN) compromise – weakness with spasticity, as well as brisk reflexes and ankle clonus. In addition, loss of sensation below level of involvement and autonomic dysfunction may be evident. Other signs include Lhermitte’s sign (an electric shock-like sensation in the neck on flexion of the neck), a positive Hoffmann’s reflex, Babinski’s sign and scissoring gait in some patients. Central cord syndrome is associated with certain types of injuries such as neck hyperextension, often in a patient with pre-existing osteophytes encroaching upon the spinal canal.

Diagnosis is usually supported by the use of magnetic resonance imaging (MRI) unless...
contraindicated. In addition to sagittal and axial views, parasagittal oblique views can be used to visualise neural foramina perpendicular to the plane of root exit (Figure 2). This enhances the sensitivity of MRI for the detection of small disc prolapses encroaching upon the exiting nerve root. If MRI is contra-indicated, computed tomography (CT) and/or CT myelogram are used. Electrophysiological studies are performed only when there is diagnostic uncertainty.

An early study in 1963 followed 51 patients with cervical radiculopathy over two to 19 years. In this cohort, no patient with radicular pain progressed to have myelopathy. In a survey of 500 radiculopathic patients with a median duration of follow-up of 4.9 years, recurrence of the condition occurred in 31.7%, and 26% underwent surgery for cervical radiculopathy. Radicular pain and focal neurology were predictors for operation. In a cohort study of 26 consecutive patients with radiculopathy followed up over 1 year, over 90% of patients improved without surgery; operative management is therefore reserved for patients with intractable pain or progressive neurology. In the case of myelopathy, there are no large randomised trials on which to base treatment recommendations but for patients with more severe myelopathy, progressing deficits or acute deterioration, surgical decompression is recommended. Surgery to prevent neurological injury in patients with asymptomatic cervical spondyloitic disease is not recommended as risk of minor trauma causing deterioration is very low.

Operative Technique

The technique used for ACDF varies widely among surgeons. We outline our routine technique.

Positioning

The patient is positioned supine with a vacuum horseshoe-shaped sandbag placed in the nape of the neck, supporting the head bilaterally. Position is neutral, and horizontal. Slight head-up, or even head-down tilt may be used to facilitate visualisation of a specific disc space.

Skin incisions and platysma division

A 4 cm transverse skin crease incision is made at the appropriate level. Anatomical landmarks are used to identify the correct level e.g. thyroid cartilage at the level of C4 and cricoid cartilage at C6. Pre-incision fluoroscopy is used by some surgeons to confirm the level of the approach. The skin incision extends medially from the anterior border of right sternocleidomastoid muscle (SCM) (mainly for the ease of right-handed surgeon). The platysma is exposed and then divided along the direction of the muscle fibres (although some prefer dividing the platysma transversely).

Surgical plane and discectomy

The anterior triangle is then dissected, developing a plane between carotid sheath laterally and the larynx and oesophagus medially, as shown in Figure 3. The carotid pulse should be confidently identified using a gloved finger inside the wound. The midline structures are retracted en bloc to avoid retraction on the recurrent laryngeal nerve (RLN). An avascular plane is dissected down to the longus colli muscles, which are then undercut bilaterally using diathermy and a peristeal elevator. Toothed self-retaining retractors are inserted under the longus colli fibres to provide a clear surgical view. Fluoroscopy is always used at this stage to confirm the operating level. Any anterior osteophytes may be removed using electrical drill or Kerrison punch. Caspar pins are used to distract adjacent levels. Discectomy is performed using a size 15 scalpel, straight microrongeurs and microcurettes under the operating microscope. Posterior osteophytes and the posterior aspect of the uncus are removed with the high speed drill, curettes and micro upcuts. The senior author recommends use of a match-head drill to perform this manoeuvre. The posterior longitudinal ligament (PLL) is carefully opened, away from the site of maximal neural compression. This is facilitated with a size 10 Rhoton hook and an upcurved Karlin blade. The ligament is resected using a 1 mm upcut to enable good visualisation of the dura and the nerve root origins. A 2 mm upcut is sometimes used at this stage. A 16 Rhoton hook is useful to probe the exiting foramen.

Graft

A PEEK cage packed with bone chips/dust obtained from removal of osteophytes is widely used as graft material for interbody fusion. The cage may be straight or incorporate a 5 degree angulation to correct kyphotic deformity. A number of grafts have been used to promote fusion. Autologous bone grafts are preferred to promote osteogenesis, osteoinduction and osteoconduction; these are usually acquired locally from osteophytes. In order to reduce donor site (traditionally iliac crest, fibula or rib) morbidity, such as pain, infection and haematoma, a number of substitutes such as allogenic bone graft and synthetics have been developed. There are also other options including ceramics and more controversially, bone morphogenic proteins (BMP). In addition, cages are generally made of plastics e.g. polyetheretherketone (PEEK) or metal e.g. titanium. Carbon fibre cages have also shown promising fusion rates.

Plate vs. no plate

There is currently no consensus in the option of anterior plates in ACDF. Our centre does not routinely use anterior cervical plates when performing a 1 or 2 level ACDF. A recent randomised trial indicated that multiple-level fusions may have better clinical outcome when a dynamic plate design is used but the use of a plate in single-level ACDF remains controversial. Plating in anterior cervical operation was initially developed for cervical spinal trauma such as fractures and dislocations. For the treatment of cervical spondylotic discopathy, it may confer the theoretical benefit of additional stability, maintenance of cervical lordosis and prevention of extrusion of bone graft material. A number of plating and fixation device designs have been developed – dynamic plate, locking screws to promote stability and alignment, and to reduce risk of visceral damages. A zero-profile system fixing the cage onto vertebral body with screws has shown comparable clinical outcomes and fusion rates relative to using anterior cervical plating, and is reported to have reduced risk of dysphagia or degenerative change of adjacent segment. More recently, bioabsorbable plates appear to achieve fusion rate and outcome comparable to the results associated with metallic plates.

Postoperative Care

Post-operatively, it is imperative to monitor the patient’s airway and neurological function with clear documentation. A rapidly developing wound haematoma can threaten airway patency and may require immediate evacuation. Any impairment of neurological function warrants an MRI scan to assess the cause and guide treatment options. Some surgeons request a post-operative cervical X-ray to confirm operative level, cage position and the position of any plating system (Figure 4). This rarely changes clinical management and is of doubtful clinical value.

Figure 4: An example of post-operative cervical radiograph after an ACDF
Measured outcomes
With cervical myelopathy, 50 to 80% of patients are reported to improve after surgery, while 5 to 30% continue to report ongoing or progressive symptoms. Positive prognostic factors in improving the patient-identified clinical outcome (as defined by modified Japanese Orthopedic Association scale) were younger age, shorter duration of symptoms, non-smoking status, and lack of significant gait impairment.

Factors reported to predict a poor response to surgery include older age, intramedullary signal abnormality on MRI, especially if multi-segmental and with abnormalities on T1 as well as T2-weighted images, more severe preoperative disability, longer duration of symptoms preoperatively, narrow preoperative canal size and multisegmental compression.

The surgical outcome for cervical radiculopathy is more equivocal. Randomised controlled trials showed that it provides short term benefit in terms of pain and neurological deficit relative to conservative treatment but by one to two years, there was no significant difference in outcome. Therefore conservative management was recommended by the authors as the initial modality of treatment.

Alternative treatments
Non-surgical options generally involve pain management and physiotherapy. Of note, a 10-year prospective randomised study involving 64 patients showed no significant benefit with surgical treatment for mild to moderate cervical myelopathy. Neuroprotective treatments such as rizulo, a sodium-glutamate antagonist are also being trialled at the moment.

The main anterior surgical alternatives to ACDF in the treatment of degenerative cervical diseases include anterior corpectomy and anterior discectomy without fusion. Posterior decompression (with or without fusion) via a limited exposure and foraminotomy (for anterior discectomy without fusion. Posterior diseases include anterior corpectomy and trialled at the moment.

Of note, a 10-year prospective randomised pain management and physiotherapy. The use of an implant to act as a spacer for fusion has become increasingly common, but a prospective, randomised trial suggested that even though the incidence of fusion was indeed higher, patient satisfaction and rate of return to preoperative activity level were similar regardless of an ACD or ACDF. Another trial showed that posterior cervical foraminotomy, ACDF and anterior cervical discectomy without fusion are equally successful in treating cervical radiculopathy caused by a unilateral acute hemiated cervical disc.

ACDF vs cervical arthroplasty
The use of an artificial joint instead of fusion to retain mobility at the level of operation has long been proposed. A metal-on-metal, ball-in-socket Cummins-Bristol design reported outcomes in 1998. Not only does it have the potential to provide a better range of movement but it also theoretically reduces motion and pressure at adjacent segment and hence incidence of adjacent segment disease (ASD). Nonetheless, a number of complications such as screw pullout had been reported and surgical removal of the hardware proved to be considerably difficult.

A range of new designs and materials have been developed. Examples include the second-generation Bristol design (also known as Prestige) which replaced the inferior hemispherical cup of the Cummins design with a shallow ellipsoid saucer to allow for more movement, and they have shown promising results in the trials. Another design known as the Bryan disc adopted a metal-on-plastic model and also showed hopeful preliminary results.

The literature has however not shown arthroplasty conferring significant long-term advantage: a Cochrane review with 2400 participants showed a small but statistically significant favourable outcome for arthroplasty compared to ACDF but it was withdrawn due to non-compliance with the Cochrane Commercial Sponsorship Policy. Another systemic review suggested no superiority of cervical total disc replacement relative to fusion operation. Another meta-analysis showed that arthroplasty does not reduce the rate of ASD compared to ACDF. More studies are required to confirm its efficacy and safety.

Complications
Factors associated with increased operative risk have included: increasing age, medical comorbidity (American Society of Anesthesiology (ASA) class > 2), chronic obstructive pulmonary disease, bleeder disorder, coexisting diabetes mellitus, OPLL and longer operative duration. A large retrospective study also suggested that the male gender increased the risk of airway complications.

Complications of ACDF (with or without fusion) can be classified as:
1) general complications e.g. anaesthetic risks, infection and haemorrhage;
2) access-related complications e.g. oesophageal, neurovascular and tracheal damage;
3) disectomy- and fusion-related device-related risks e.g. damage to nerve root or spinal cord and loosening of screws;
4) risks of non-union, compressive residual disease and ASD.

A summary of complication rate from various recent studies is shown in Figure 5.

<table>
<thead>
<tr>
<th>Key Complications</th>
<th>Complication rate / %</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-op haematoma</td>
<td>0.2 to 5.6</td>
<td>Tew, Fountas, Nanda</td>
</tr>
<tr>
<td>RLN palsy</td>
<td>0.05 to 7.1</td>
<td>Robinson, Tew, Flynn, Fountas, Nanda</td>
</tr>
<tr>
<td>Dysphagia</td>
<td>0.15 to 9.5</td>
<td>Tew, Fountas, Nanda</td>
</tr>
<tr>
<td>Horner’s syndrome</td>
<td>0.02 to 3.6</td>
<td>Robinson, Tew, Flynn, Fountas</td>
</tr>
<tr>
<td>Pharyngeal or oesophageal perforation</td>
<td>0.1 to 0.3</td>
<td>Tew, Fountas, Nanda</td>
</tr>
<tr>
<td>Durotomy</td>
<td>0.5 to 1.3</td>
<td>Fountas, Nanda</td>
</tr>
<tr>
<td>Worsening neurology</td>
<td>0.2 to 0.88</td>
<td>Tew, Flynn, Fountas</td>
</tr>
<tr>
<td>Wound infection</td>
<td>0.1 to 9.5</td>
<td>Robinson, Fountas, Nanda, Gruskay</td>
</tr>
<tr>
<td>Graft extrusion</td>
<td>0.0 to 0.88</td>
<td>Tew, Fountas, Nanda</td>
</tr>
<tr>
<td>Mortality</td>
<td>0.0 to 0.2</td>
<td>Robinson, Tew, Flynn, Fountas, Nanda, Gruskay</td>
</tr>
<tr>
<td>Overall Complication</td>
<td>0.45 to 19.6</td>
<td>Robinson, Tew, Flynn, Fountas</td>
</tr>
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</table>

There is insufficient evidence to support differences in rates of complications across surgical techniques. A retrospective American study with 36000 patients found an overall complication rate of 15.6% after ACDF, 29.2% after posterior fusion, 41.1% after combined anterior and posterior fusion, and 22.4% after laminoplasty. The author acknowledged that the rates are considerably higher than other similar studies and attributed the discrepancy...
to their accurate data sourced from commercial claims, outpatient services and Medicare databases, reducing the risk of losing follow-up outcomes. However, different techniques are often associated with different types of complications: for example, 1) dysphagia is more frequent following anterior surgery, 2) wound infection is more common following posterior surgery, and 3) higher rates of axial pain are observed following laminoplasty compared to ACDF.

**Dysphagia and dysphonia**

Dysphagia and dysphonia are both common complications after ACDF. They are likely to be multifactorial such as secondary to visceral oedema or neuropraxia of RLN or superior laryngeal nerve secondary to retraction. The majority (67 to 100%) of patients with vocal cord palsy recover within 12 months and most recover within 6 to 12 weeks. It is imperative the surgeon is aware of the anatomy (e.g. the RLN is located in the tracheoesophageal recess) during retraction. Due to the increased risk of dysphonia from the anterior approach, professional speakers and singers need to be counselled with care.

**Equipment-related**

With respect to locking plate-related complications, a retrospective study involving 2000 patients estimated a 7.7% complication rate, including loosening or breaking of the plates and screws or malpositions that threatened tracheoesophageal or neurovascular structures. These were radiologically diagnosed and only a small number required re-operation. In addition, plating appears to increase the risk of adjacent level ossification (ALO), the clinical significance of which is debatable.

**Conclusions**

Six decades after the procedure of ACDF was first used to treat degenerative spine diseases, the literature has supported its position as the mainstay of treatment for a number of cervical spinal pathologies. It is an established, safe and effective procedure, with an acceptable complication profile. A variety of techniques have been adopted and in this article we have outlined the indications and technique we routinely use in our centre. Some issues remain controversial – such as the use of plating and arthroplasty, and require further studies.

**REFERENCES**

The aim of this tiny reference book is to provide the clinician with a pocket-sized, comprehensive manual on diagnosis and management of Alzheimer’s disease (AD). It is evidence-based and up-to-date; it encompasses the biology of AD, psycho-social aspects and brief discussion of differential diagnoses. The referencing is comprehensive. Key drug trials and other research studies are included and summarised. Each of the 14 chapters is written by an expert in that subject area.

The book not only serves as a quick reference for practising clinicians but also offers guidance on multi-faceted aspects of management, relevant both to patients and their caregivers. It is designed to meet the needs of advanced medical students as well as doctors in neurology, psychiatry and general medicine.

The information is succinct and clearly written, being organised into chapters dealing with particular aspects of disease identification and/or management. The first chapter is an overview of dementia, describing the different types and their prevalence, and also the key presenting features. Subsequent chapters deal exclusively with Alzheimer’s disease. The chapters are well structured and address current theories of pathophysiology, knowledge of the genetics in familial forms of the disease and risk factors for sporadic disease, epidemiology, presenting features diagnosis and how to communicate a diagnosis to a patient. A holistic view of management is also provided. Pharmacological treatments, end of life care, social care and safety, legal issues and driving are all discussed. The concluding sections of each chapter identify any areas of research gaps in the field and avenues of possibility for further exploration.

The last chapter outlines various cases to illustrate and emphasise key concepts. In terms of format, the information within each chapter is arranged under a main heading and then various subheadings. This assists the reader when looking for a specific topic. At the beginning of each chapter there is a list of key points or take home messages that should be gleaned from the chapter. There are some illustrations and images included but these are mainly black and white; they are of varying use and appeal. Colour print could have enhanced the illustrations and provided more clarity but additional costs, no doubt. The very small print lends itself to using the book as a mini-reference rather than a mini-introduction to be read from cover to cover. In any case, there is too much medical terminology for it to be recommended to a lay person or, say, a non-clinical scientist.

The purpose of the book is to provide a quick and easily accessible reference text and update for clinicians working in this field or for those new to the profession. I feel that the authors have succeeded in doing this. The book is small and easily transportable and is not too expensive.