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Cervical radiculopathy

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Abstract Cervical radiculopathy is a common clinical scenario. Patients with radiculopathy typically present with neck pain, arm pain, or both. We review the epidemiology of cervical radiculopathy and discuss the diagnosis of this condition. This includes an overview of the pertinent findings on the patient history and physical examination. We also discuss relevant clinical syndromes that must be considered in the differential diagnosis including peripheral nerve entrapment syndromes and shoulder pathology. The natural history of cervical radiculopathy is reviewed and options for management are discussed. These options include conservative management, non-operative modalities such as physical therapy, steroid injections, and operative intervention. While the exact indications for surgical intervention have not yet been elucidated, we provide an overview of the available literature regarding indications and discuss the timing of intervention. The surgical outcomes of anterior cervical decompression and fusion (ACDF), cervical disc arthroplasty (CDA), and posterior cervical foraminotomy (PCF) are discussed.

Keywords Cervical radiculopathy · Physical examination · Non-operative management · ACDF · Cervical disc arthroplasty · Posterior cervical foraminotomy

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Introduction

Cervical radiculopathy is a clinical condition resulting from compression of cervical nerve roots. The clinical manifestations of cervical radiculopathy are broad and may include pain, sensory deficits, motor deficits, diminished reflexes, or any combination of the above. Similarly, there are a variety different pathophysiologic processes which may result in dysfunction of the cervical nerve roots. In recent years, there has been considerable work performed in understanding the natural history of cervical radiculopathy as well as clarifying operative indications and outcomes following surgery. The following is a review of these recent developments.

Epidemiology

The most widely cited study of the epidemiology of cervical radiculopathy was performed between 1976 and 1990 in Rochester MN [1•]. These authors found that the annual incidence of cervical radiculopathy was 107.3 per 100,000 for men and 63.5 per 100,000 for women. A more recent study from the US military found an incidence of 1.79 per 1000 person-years [2]. The incidence of cervical radiculopathy seems to peak in the fourth and fifth decades in life [1•, 3]. Risk factors for cervical radiculopathy include white race, cigarette smoking, and prior lumbar radiculopathy [3–5]. Other risk factors that have been proposed include lifting heavy objects, frequent diving from a board, driving equipment that vibrates, and playing golf [3]. Generally speaking, the incidence of trauma preceding the onset of cervical radiculopathy is relatively low [1•, 3]. Up to 30 % of patients report the onset of pain when sitting, walking, or standing [3].

Pathoanatomy and etiology

The pathoanatomy of cervical radiculopathy involves compression of the cervical nerve root [6]. Compression of the cervical nerve root may occur due herniation of disk material or bony osteophytes that impinge on the cervical nerve root. Epidemiologic studies have shown that the C7 root (C6-7 herniation) is the most commonly affected, followed by the C6 (C5-6 herniation) and C8 (C7-T1 herniation) nerve roots. Impingement of the nerve root by disc material likely leads to nerve damage both by mechanical and chemical pathways. Mechanically, compression of the nerve likely leads to localized ischemia and nerve damage. Equally important, however, is the chemical cascade triggered by the nucleus pulposus on the nerve. Disc degeneration and the local ischemia triggers a pro-inflammatory cascade mediated by tumor necrosis factor-alpha (TNF-α), interleukin factor-6 (IL-6), and matrix metalloproteinases (MMPs) [7, 8]. This cascade leads to further sensitization and increased pain in the area [8].

The majority of cases of cervical radiculopathy, however, are not due to "soft" disc herniation, but rather due to cervical spondylosis. Cervical spondylosis refers to the degenerative changes that occur in the cervical spine with age. In these cases, the breakdown of the disc with age leads to decreased disc height and foraminal narrowing. The decreased disc height then results in increased loads placed through the intervertebral joints of Luschka (uncinate joints) as well as the vertebral body. This, in turn, leads to bony hypertrophy. Hypertrophy of the uncinate joint, in particular, leads to foraminal stenosis and cervical radiculopathy. It is suspected that some individuals have a genetic predisposition to disc degeneration although only modest correlations have been found in genome wide association studies [9].

Natural history

To date, there have been no high-quality studies that have demonstrated the natural history of cervical radiculopathy. The epidemiologic study by Radhakrishnan, et al. showed that at 4-year follow up, nearly 90 % of patients with cervical radiculopathy were either asymptomatic or only mildly symptomatic [1•]. Other authors have shown similar findings [10]. Similarly, a commonly cited "classic" paper from 1963 found that at 2–19-year follow-up, the vast majority of patients with cervical radiculopathy had no symptoms (43 %) or mild, or intermittent symptoms (29 %) [6, 11]. These data have led most investigators to conclude that cervical radiculopathy is a self-limited phenomenon in most cases.

A recent systematic review of literature seeking to evaluate the course of untreated cervical radiculopathy concluded that the majority of patients see substantial improvements 4–6 months that are generally maintained over 2–3 years [5]. This systematic review also showed no progression to myelopathy in patients with cervical radiculopathy and also showed that workers compensations claims were correlated with more invasive treatment and a poorer prognosis [5].

Diagnosis

History and physical examination

As noted above, cervical radiculopathy may present with a broad variety of clinical manifestations ranging from pain to objective weakness and diminished reflexes. An accurate history is a critical first step in the diagnosis of radiculopathy. Examiners must focus on the location and patterns of pain, paresthesias, sensory deficits, and motor deficits. In most cases, cervical radiculopathy can be diagnosed based on the patient history alone [12].

Unlike patients with axial neck pain, patients with radiculopathy usually present with unilateral pain [6]. This neck pain may be associated with radiation into the ipsilateral arm in a dermatomal distribution; however, an absence of pain in the arm does not exclude the presence of cervical radiculopathy. In addition to radiation down the arm, the patient may complain of loss of sensation along the same dermatomal distribution or have weakness along the corresponding myotome. A list of the common dermatomal and myotomal distribution and their corresponding nerve roots are shown in Table 1. There is moderate inter-observer reliability for strength and sensory testing (Kappa 0.40–0.64) [13]. Yoss et al. found that diminished reflexes were most commonly correlated to the pathology identified at surgery (82 %), followed by motor weakness (77 %), and diminished sensation (65 %) [14].

Provocative tests to assist in the diagnosis of cervical radiculopathy include the Spurling test, the shoulder abduction test, Valsalva maneuver, Neck distraction, and Elveys upper limb tension test (ULTT) [12, 15•]. The Spurling test is the most commonly used of these examination maneuvers. A number of different variations of the Spurling test have been described (i.e., axial loading, rotation only, or rotation with neck extension) [6, 15•, 16]. In theory, all three of these maneuvers should result in a narrowing of the neural foramen and reproduction of the patient's symptoms. A majority of studies testing the efficacy of physical examination maneuvers suffer from small sample sizes. A systematic review of physical examination maneuvers in the setting of cervical radiculopathy found that the Spurling test was most sensitive (ranging from 30–100 %) and specific (75–100 %) when rotation and extension were combined [15•]. The largest of these studies showed that the Spurling test had low sensitivity (30 %) but a high specificity (94 %) [17]. A Spurling test with purely axial loading without rotation or extension has been shown to be the least sensitive and specific form of this test [12].

Table 1 Distribution of sensory and motor weaknesses typically seen with cervical radiculopathy

Level	Muscle weakness	Sensory deficits/location of pain	Reflex
C5	Deltoid	Lateral arm	Biceps
C6	Biceps, wrist extension	Radial forearm, radial two digits	Brachioradialis
C7	Triceps, wrist flexion	Middle finger	Triceps
C8	Finger flexors	Ulnar two digits	
T1	Hand intrinsics	Ulnar forearm	

The shoulder abduction test checks for the relief of symptoms with shoulder abduction as the nerve is taken off tension. Investigators have found the sensitivity of this test to range from 17–78 % with a specificity ranging from 75–92 % [15•]. Other tests such as the Valsalva maneuver (increasing pain with the Valsalva maneuver; sensitivity 22 %, specificity 94 %), traction/distraction (improvement in pain with traction; sensitivity 44 %, specificity 90–97 %), and ULTT (increased pain with traction of the upper extremity; sensitivity 72–83 %, specificity 11–33 %) have not been as well studied [12, 15•].

When diagnosing a patient with radiculopathy, it is important to test for cervical myelopathy. Patients with myelopathy will present with upper motor neuron signs including hyperreflexia, changes in gait, and also have difficulty with fine motor tasks (changes in handwriting, buttoning shirts, etc.). Other pathologies that might be confused with cervical radiculopathy include peripheral nerve compression syndromes (e.g., median or ulnar nerve entrapment). It is also important to be aware that patients may also present with peripheral entrapment and cervical radiculopathy, a phenomenon known as "double crush." Finally, shoulder pathology must be considered and ruled out in these patients as shoulder girdle pain is frequently the most common presenting symptom of cervical radiculopathy [6]. Selective injections (for example, intraarticular subacromial shoulder injections) can be helpful in establishing a diagnosis. Other items on the differential diagnosis include cardiac pain, herpes zoster (shingles), Parsonage-Turner syndrome, postmedian sternotomy lesion, intra and extraspinal tumors, and thoracic outlet syndrome [16].

Imaging

Imaging for cervical radiculopathy typically consists of radiographs and advanced imaging including a computed tomography (CT) scan and magnetic resonance imaging (MRI). Radiographs typically consist of AP and lateral views of the cervical spine. Evaluation of these radiographs includes paying careful attention to disc height and the presence of degenerative changes. Oblique radiographs of the cervical spine may be obtained to allow for better evaluation of the foramen.

Advanced imaging typically consists of an MRI of the cervical spine to evaluate for soft tissue sources of impingement (i.e., "soft" disc herniation) as well as signs of myelomalacia. In cases where MRI cannot be performed, a CT myelogram may be utilized. CT scans are better suited to the evaluation of bony pathology and may be used to better delineate "hard" disk impingement.

Additional testing

Electromyographic (EMG) studies might prove useful in differentiating peripheral nerve entrapment syndromes from cervical radiculopathy. However, interpretation of EMG results must be performed with the clinical context in mind as they can commonly produce false-positive and false-negative results. Some authors have shown better results for cervical surgery in patients with positive findings on a preoperative EMG when corroborating imaging findings (e.g., MRI) were also present [18]. EMG used without imaging, however, has been shown to be a relatively poor tool for localization with only 42 % of EMG findings correlated to findings at the time of surgery [19].

Non-operative treatment

Non-operative treatment of cervical radiculopathy consists of a number of different modalities including immobilization, physical therapy, traction, manipulation, medication, and cervical steroid injection [6]. Authors have reported good to excellent outcomes in up to 90 % of patients with non-operative management of cervical radiculopathy [20].

Immobilization

Following the onset of symptoms, a brief period of immobilization may be attempted [6, 21]. Typically, a soft cervical collar is sufficient to provide the immobilization needed to minimize motion and reduce nerve root irritation [21]. Even though cervical collars are prescribed by convention, there is little evidence in the literature supporting their use [6, 19]. Additionally, while early immobilization might help in limiting inflammation, care must be taken with long-term immobilization (more than 1–2 weeks) as it can lead to deconditioning and atrophy of the muscles in the neck [6, 19].

Physical therapy

A number of authors have investigated the effect of physical therapy against a wide variety of therapeutic interventions. These include intermittent cervical traction [22], immobilization [23], and ultrasound and infrared treatment [24]. A recent systematic review of these and eight other studies found that exercise regimens typically focused on strength training and stretching of the neck muscles [22]. Additional considerations in designing a physical therapy program for radiculopathy include the patient's general functional status (aerobic training if aerobic conditioning is suboptimal) and strength training of the neck and chest. A well-designed physical therapy program should progress the patients through these stages as pain improves, beginning with gentle range of motion exercises, and adding strengthening and conditioning activities once the acute symptoms subside [6]. Finally, physical therapy programs should include some component of postural and ergonomic training [21].

Exercise regimens in the literature vary widely in their intensity and duration, ranging from twice a week to once a day and lasting from as little as 10 days to as long as 10 weeks [22]. Studies of physical therapy vs. other conservative interventions suggest that there might be a moderate short-term benefit in neck pain and grip strength with physical therapy, but these benefits dissipate at 6 months to a year [22]. Care must be taken when interpreting these findings; however, as the majority of literature, evaluating physical therapy typically uses at least one other conservative modality (e.g., traction) in treating these patients. Some authors believe that physical therapy does not change the natural course of radiculopathy [6].

Traction

Cervical traction is sometimes considered a modality of physical therapy [19, 21] but is considered separately here as there are several studies that have examined its efficaciousness. Cervical traction can be applied manually by a physical therapist or mechanically with a series of increasing weights. Traction weights can range from 5 to 12 kg [25]. Several studies have examined the efficaciousness of cervical traction in isolation or in combination with an exercise regimen [22, 25–27]. These studies generally do not support a widespread role for cervical traction as most randomized control trials show similar results in patients who did and did not receive cervical traction, particularly when using validated outcome instruments [26, 27]. There may, however, be a small benefit to traction when non-standardized outcome measures are used [19, 26]. Care must be taken in the use of traction in patients with myelopathy as traction may result in stretching of the spinal cord over a compressive lesion [6].

Manipulation

Recently, Gross et al. performed a Cochrane review examining the effect of manipulation and mobilization as a treatment modality for neck pain [28]. These authors generally found that the literature in this area was of low to very low quality. They showed improved immediate pain with manipulation compared to immobilization and that repeated manipulations might provide some benefit [28]. However, these authors were able to find no benefit for manipulation at short-term and intermediate follow-up. Additionally, when manipulation was compared to mobilization and physical therapy, there were no differences in outcome at immediate, short-term, and intermediate follow-up [28].

The uncertain benefits provided by manipulation must be considered in the context of the potential for catastrophic complications that exists with cervical manipulation [6, 29–33]. While the exact rate of vertebral artery injury following manipulation is unknown, the odds ratio for vertebral artery dissection and vertobrobasilar artery stroke in young patients following cervical manipulation ranges from 3 to 12 [31]. A case series of 13 vertebral artery dissections following manipulation reported one death due to massive cerebellar stroke, three patients requiring cerebellar decompression due to impending herniation, five patients requiring stenting, and one patient requiring thrombolysis [33].

Medication

Oral analgesic medications are commonly used in managing patients for cervical radiculopathy. There are two broad categories of medications that may be considered: narcotic and non-narcotic medications. When possible, the use of narcotic medications should be avoided as they can have consequential side effect and prolonged use can lead to dependency and can make postoperative analgesia more challenging. However, if the patient's pain at presentation is poorly controlled, a short course of oral narcotics can be beneficial.

Of the non-narcotic medications, non-steroidal anti-inflammatory drugs (NSAIDs) are the mainstay of management. NSAIDs have both analgesic and anti-inflammatory effects [21] and provide relief by targeting the inflammatory cascade at the nerve roots. Oral corticosteroids (a week-long methylprednisolone taper) are sometimes used in the acute phase to manage the inflammatory cascade. However, there is no evidence to support their efficacy for this indication, and their use must be weighed against the risk of complications such as hyperglycemia, osteonecrosis, and infection [6].

Corticosteroid injections

Cervical epidural spinal corticosteroid injections are commonly used as an adjunct to the above non-operative management techniques. These injections allow for local delivery of a high dose of corticosteroids that are believed to work through several pathways: (1) reduce inflammation at the nerve root, (2) reduce nociceptive input from somatic nerves, (3) stabilize neural membranes, (4) block the synthesis of pain-mediating neuropeptides, (5) break up adhesions at the site of injections, and (6) block C-fiber activity in the dorsal root ganglion [6].

The evidence supporting the routine use of epidural steroid injections is sparse. There is one trial that compared injection of steroids in the epidural space to lidocaine injections in the local musculature [34]. These authors found that 68 % of patients receiving epidural steroid injections had "good" or "very good" pain relief at 12 months, compared to 11 % in the local injection group. A review of literature on the topic has found that epidural corticosteroids may lead to short-term improvement in patient symptoms [35]. Other studies on the topic [36•, 37–40] have compared epidural steroid injections to local injections or other therapeutic interventions (e.g., oral analgesia, local anesthetic injections); there are no trials comparing epidural injections to the natural history of radiculopathy [36•]. The majority of these trials showed that steroid injections had no benefits when compared to injections of local anesthesia [36•].

While complications from cervical injections are rare, there are both major and minor complications associated with this procedure. Minor complications include adverse reactions and temporary deficits such as vasovagal reactions, transient neurologic deficits, hypersensitivity reaction, and skin rashes [41]. Major complications that have been reported include transient ischemic injury, brain infraction, spinal cord injury, cortical blindness, high spinal anesthesia, seizures, bleeding, and death [41]. While these are all recognized complications of epidural injections, there is little data regarding the incidence of these complications.

Operative treatment

Indications

There is no clearly established consensus regarding indications for surgery in patients with cervical radiculopathy [6, 16, 19]. Given that most patients with cervical radiculopathy improve with conservative management, a trial of observation is warranted in patients without any concerning signs or symptoms. Concerning signs or symptoms that might merit early surgical intervention include progressive neurologic deficits, signs of myelopathy, fractures or other signs of cervical instability or ligamentous injury, osseous lesions, or destruction [42•]. In the absence of these signs, a trial of non-operative management is typically attempted.

The length of non-operative management that must be attempted is unclear. In their systematic review, Wong et al. noted that most patients experienced substantial improvement in 4–6 months [5]. Recent work has also shown that a longer duration of symptoms preoperatively corresponds to worse outcomes after surgery [43•]. This finding has been corroborated by other authors [44]. Burneikiene et al. authors found significantly better arm pain scores in patients who underwent decompression within 6 months of symptom onset [43•] and therefore recommended 6 months as the cutoff for non-operative management. A randomized-controlled trial is now underway to clarify indications [45].

Anterior approach

Anterior cervical discectomy

Anterior decompression has been the workhorse approach to the problem of cervical radiculopathy. The procedure most commonly performed is anterior cervical decompression and fusion (ACDF). Decompression involves removal of all disc material anteriorly from uncinate process to uncinate process; this discectomy may also be accompanied by an anterior foraminotomy if needed. Following decompression of the nerve root, an interbody graft is usually placed to restore cervical disc height and lordosis. There are a variety of graft materials [46] and instrumentation options available to assist with anterior fusion.

Historically, surgeons would perform an anterior discectomy without fusion (ACD). There is little evidence in the literature comparing ACD to ACDF. Studies that have examined long-term results of ACD show good to excellent results in 82–96 % of patients with radiculopathy [47, 48]. Another study found an almost 10 % reoperation rate in patients undergoing ACD [49] with neck and interscapular pain being a common postoperative problem, persisting almost 4 years in 4 of 55 patients. Pain and local kyphosis have been reported as complications of ACD by other studies as well [50]. Current practice favors ACDF because it assists with indirect decompression of the nerve root (by restoring disc height and opening the foramen in the cephalocaudal direction) and offers more predictable outcomes. Recent advances in bone graft substitutes and subsequent elimination of the need for iliac crest bone autograft has reduced donor site morbidity as well.

The best data on outcomes following ACDF in cervical radiculopathy has actually been obtained from studies of cervical disc arthroplasty [51–56, 57•]. These were multicenter prospective randomized trials with follow-up now ranging from 4 to 6 years. These studies show a significant and durable improvement in clinical outcomes (NDI) with neurologic success of 87.8 % [57•]. Implant-related complications in this group were 6.9 %. Additionally, there was a 12.2 % rate of secondary procedures by the 4–6-year follow-up interval with a 9.7 % reoperation rate at the index level and 8.5 % rate of operation at the adjacent level [57•]. A multivariate analysis has shown that low levels of preoperative disability, non-smoking status, male sex, good hand strength, and active range of motion in the neck are independent predictors of improved outcome following ACDF [58].

In addition to adjacent level pathology, pseudarthrosis remains a concern following ACDF. A recent meta-analysis reported an overall pseudarthrosis rate of 2.6 %; 0.9 % when autograft was used and 4.8 % when allograft was used [46] although the exact rate of pseudarthrosis was difficult to determine given the different methodologies and follow-up times used in the literature. When the number of levels addressed is increased, the rate of pseudarthrosis likely increases as well. Rates of pseudarthrosis as high as 49 % have been reported with three-level ACDF [59]. Other limitations of anterior surgery include the limited number of levels that can be addressed through this approach. While up to four levels may be addressed through a single incision, these procedures can result in increased rates of pseudarthrosis, dysphagia, and implant-related complications.

Some authors have advocated an anterior foraminotomy as a method to decompress the spine [60]. In this procedure, just enough disc material is removed to allow for a foraminotomy to be performed anteriorly. While some authors report good outcomes with this procedure [61–63], at least one study reported unacceptably high re-operation rates with this procedure [64]. Appropriate patient selection is critical if this procedure is to be attempted.

Cervical disc arthroplasty

Cervical disc arthroplasty (CDA) is a relatively new technique that has now been validated in several prospective, randomized clinical trials [53–56, 65, 66]. Cervical arthroplasty is performed through the same approach as an ACDF but instead of graft material, a prosthesis is placed in the decompressed disc space. The rationale behind CDA is that this procedure maintains motion at the affected segment and as a result spares degeneration at the adjacent segment and will reduce the need for secondary procedures. Several prosthetic designs are now commercially available [53–56, 65, 66].

In the past several years, the results of several randomized clinical trials have been published, and these have been subjected to a number of meta-analyses [57•, 67–70]. The most recent of these systematic reviews [57•] which includes 4 to 6-year data concluded that CDA was superior to ACDF with regards to overall success, NDI success, neurologic success, implant and surgery-related adverse events, secondary procedures, functional outcomes, patient satisfaction, and adjacent segment degeneration. A cost-effectiveness analysis of CDA vs. ACDF showed that CDA was more cost-effective with the sensitivity analysis revealing that this cost-effectiveness required an average implant survival of a little over 9 years [71]. Until that long-term survivorship data becomes available, it is probably premature to recommend CDA as the first-line of treatment for cervical radiculopathy; however, the data currently available are certainly very promising. When indicating patients for CDA, it is important to remember the strict inclusion and exclusion criteria of the trials cited above; most studies excluded patients with multilevel degenerative disease and spondylotic changes. Broadening the indications of CDA to include this subset of patients might result in inferior outcomes.

Posterior approach

Posterior decompression

A posterior cervical foraminotomy (PCF) is a valuable alternative to the anterior approach. A PCF involves widening the foramen and indirect decompression of the nerve roots and usually requires a partial laminotomy and medial facetectomy. A PCF can avoid the morbidity associated with anterior approach (dysphagia, implant-related complications) and can preserve motion in the spine without the need for an implant. The posterior approach also makes it easier to address pathology at multiple levels. The disadvantages of the procedure include an incomplete decompression due to anterior compressive pathology and continued degeneration at the involved segment necessitating reoperation. One long-term study of PCF reported a reoperation rate of 9.9 % at an average of 2.4-year follow-up [72]; however, reoperations reached 18.3 and 24.3 %, respectively, when minimum 2- and 10-year follow-up was considered. 91.4 % of patients in this series experienced symptom improvement at 1 month, and 85 % had improvement at an average of 4-year follow-up [72]. A multivariate analysis revealed that preoperative neck pain was an independent predictor of reoperation [72]. Another study reported a lower rate of reoperation (1.1 % per index level per year and 0.9 % per adjacent level per year) [73]. Most studies have reported durable long-term outcomes with this technique [72–76]. One study to examine costs found an 89 % higher cost with ACDF vs. PCF (primarily due to implant-related costs) despite similar clinical outcomes [77].

Summary

Cervical radiculopathy is a common clinical scenario and typically presents with unilateral neck pain, arm pain, or both. Patients may also present with neurologic signs such as sensory or motor deficits. It is important to differentiate cervical radiculopathy from other items on the differential diagnosis including peripheral nerve entrapment syndromes and shoulder pathology. Most cases of cervical radiculopathy are self-limited and may be managed conservatively in the absence of progressive neurologic symptoms or other concerning symptoms such as osseous lesions, etc. There are several options for conservative management, but there is little evidence to suggest that any of these interventions substantially alter the natural history of the disease. While exact surgical indications have not yet been elucidated, surgery may be considered in patients that have not responded to conservative management at about 6 months. ACDF, CDA, and PCF have all been shown to be viable surgical options available to the surgeon based on the patient's pathology and the surgeon's preference.

Compliance with ethical standards

Conflict of interest Sravisht Iyer declares that he has no conflict of interest.

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Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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