DISPLACED SUPRACONDYLAR FRACTURES OF THE ELBOW IN CHILDREN

A Report on the Fixation of Extension and Flexion Fractures by Two Lateral Percutaneous Pins

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The orthopaedic service in Tunisia was opened in 1964 with 100 beds for a population of some five million people. Referrals included patients with Volkmann's ischaemic contracture or with gangrene of the hand following supracondylar fracture of the humerus treated with the elbow in acute flexion. It was thus incumbent upon us to develop a reliable method of treatment which would avoid these tragedies without blocking the limited bed space.

CLINICAL MATERIAL

Between 1966 and 1971, 175 children were admitted to the service with displaced supracondylar fractures of the elbow across the olecranon fossa. Seventeen had flexion fractures and are the subject of the second part of this paper. One hundred and fifty-eight children had extension fractures, the distal fragment being displaced posteriorly (Fig. 1).

Because of gross oedema, thirty-two patients were treated by skeletal traction using a Kirschner wire through the olecranon, and were in hospital for an average of twenty days; two more were treated in traction after failure of closed reduction, and fourteen had closed reduction and fixation with one percutaneous Kirschner wire after the technique described by Jean Judet in 1953. In order to improve the stability one of us (M. T. K.) modified this method by using two pins, both inserted laterally so as to avoid the ulnar nerve. The remaining 110 children...
were treated by this method and are the subject of the first part of this paper. The technique and its complications are described, and the results in eighty children, examined between six months and five years later, are presented.

Clinical details—By the classification of Lagrange and Rigault (1962), all these 110 fractures were either Type 3, with rotation of the distal fragment and only one remaining point of contact, or Type 4, with no contact whatsoever. The ages of the children varied from two to fifteen years, the majority being between five and ten. There were eighty-nine boys and twenty-one girls. The fracture was on the left side in sixty-three children and on the right in forty-seven. Seventy-one patients were treated the same day; the remaining thirty-nine were treated on average three days later, the longest delay being nine days.

TREATMENT

One hundred and four of the 110 patients were treated primarily by closed reduction. Of the other six, four with grossly swollen elbows were treated first with skeletal traction for several days to reduce the oedema and then had closed reduction, while two patients each with a large open wound had open reduction. All the fractures were stabilised by two lateral percutaneous pins (Fig. 2).

Technique—Under general anaesthesia, the patient's arm was prepared and draped. Following the technique described by Charnley (1961), with the elbow in extension and the forearm supinated, the carrying angle was restored; the elbow was then flexed and the reduction confirmed radiographically. A fine Kirschner wire mounted in a chuck or electric drill was driven into the distal humeral epiphysis immediately lateral to the olecranon, entering the epiphysis at the junction of trochlea and capitellum. After crossing the fracture line the pin was drilled 4 or 5 centimetres up the medullary canal of the diaphysis. A second wire was introduced close to the first but at an angle of 30 degrees to it, and after crossing the fracture line at a point well medial to the other pin, penetrated the medial cortex of the diaphysis. Radiographs were taken (Fig. 2), and if the reduction and fixation were satisfactory, the pins were bent outside the skin to prevent migration and then cut off, a sterile dressing was applied, and a plaster back-slab made with the elbow at a right angle and the forearm in neutral rotation. The following day the cast was completed, the reduction again confirmed by radiographs, and the patient sent home. The average stay in hospital was four days. The patient was seen at weekly intervals and three or four weeks later the cast and pins were removed without anaesthetic.

COMPLICATIONS

Complications of the injury—On admission eight children had a faint or absent radial pulse; seven had lateral displacement of the distal fragment. Another patient, aged four, had an open supracondylar fracture with complete division of the brachial artery and displaced fractures of both bones of the same forearm. At operation the artery was ligated, the fracture reduced and pinned and the wound closed; the forearm fractures were then reduced and held with the cast. A stellate ganglion block was also done. The hand soon became warm and pink.

Six other patients had open fractures. One patient had open reduction through a large wound; for the others the wounds were explored and closed and the fractures then reduced and pinned in the usual manner.

Seven patients had nerve injuries. Three had a partial motor paralysis of the radial nerve with normal sensibility, and another had sensory loss only. Three patients had a median nerve injury—one complete paralysis, one motor weakness with complete anaesthesia, and the third sensory loss only. The radial nerve injuries were associated with medial displacement of the elbow, the median nerve lesions with lateral displacement. There were no ulnar nerve lesions.

Six patients, including the girl with the ruptured brachial artery, had fractures of both...
Fig. 2
Antero-posterior and lateral radiographs taken in the operating theatre immediately after reduction and pinning of an extension fracture. The pins were later bent to avoid migration and cut off outside the skin.

Fig. 3
Antero-posterior and lateral radiographs of the same elbow as shown in Figure 2, taken two years later. The distal humeral epiphysial plate appears normal, the olecranon and coronoid fossae are well maintained, and the carrying angle and mobility of the elbow are the same as on the other side.
bones of the same forearm. These were reduced and held in plaster after fixation of the supracondylar fracture.

Complications of the treatment—Of the patients with no nerve lesions before reduction, two had complete radial nerve paralysis after closed reduction, and another a complete median nerve paralysis; a fourth had motor paralysis only of the median nerve and a fifth had sensory loss only. The radial nerve lesions were associated with medial displacement of the distal fragment, and the median nerve lesions with lateral displacement. Another patient, a girl of thirteen with greenstick fractures of both bones of the same forearm, had complete paralysis and anaesthesia of the hand after operation, but no signs of ischaemia. These post-reduction palsies were no doubt due to the additional trauma of the manipulative procedures.

Infection of the elbow joint occurred in three patients, two of whom were treated immediately by drainage and closed irrigation (Compere, Metzger and Mitra 1967). The third had a low grade infection which was not apparent for three months; he was then treated with systemic antibiotics. Five other patients had pin track infections without joint involvement. None of these eight patients had an open fracture. Three children required a general anaesthetic to remove the wires, which had not been bent and had migrated.

RESULTS

Eighty children were examined on average two years after the fracture, the shortest follow-up being six months and the longest five years. Based on the classification of Lagrange and Rigault (1962), the results were divided into the following categories. Excellent—a normal arm and hand; good—either a deficit of less than 20 degrees in the range of movement of the elbow or a change in the carrying angle of less than 10 degrees (if both abnormalities were present the patient was placed in the next category); fair—a deficit in the range of movement of less than 50 degrees, or a change in the carrying angle of less than 20 degrees; and poor—the range of movement decreased by more than 50 degrees, or a change in the carrying angle of more than 20 degrees.

<table>
<thead>
<tr>
<th>Result</th>
<th>Type 3</th>
<th>Type 4</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>6</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Good</td>
<td>5</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The results are shown in Table I. Thirty-two patients (40 per cent) had an excellent result (Figs. 3 and 4). Thirty-eight patients (47.5 per cent) had a good result; twelve lost less than 10 degrees of movement; and three less than 20 degrees; the other twenty-three had a change of less than 10 degrees of the carrying angle; two of these had an increase of 6 degrees, while the rest had a decrease. Eight patients (10 per cent) had a fair result; seven had varus deformities with good mobility of the elbow; one lost 7 degrees of the carrying angle and 15 degrees of movement. Two children (2-5 per cent) had poor results, with only a few degrees of movement from the right angle. One patient had a low grade infection recognised late; the other, the girl of thirteen mentioned earlier, had a total paralysis of the median, radial and ulnar nerves after operation, and the pins were left in place for eight weeks.
A patient aged 7, sixteen months after an extension fracture of the right elbow was reduced and pinned by the method described. Movement of the elbow and the carrying angle are normal.

In general, 90 per cent of the full range of movement of the elbow was regained by a year. Improvement however continued into the fourth year, when eighteen of the nineteen patients examined had full movement and one lacked only 10 degrees of flexion.

All the open wounds healed by primary intention and the patients regained a full range of movement. There were no permanent vascular sequelae. All the children with a diminished or absent radial pulse on admission had good vascularity of the hand after reduction and all ultimately had a normal pulse. The patient with a divided brachial artery, when last seen three years later, had a normal arm and hand. All the patients with nerve lesions, whether before or after reduction, had full spontaneous recovery over the ensuing weeks. Of the five patients with pin track infections, four returned for follow-up; only one had loss of movement —15 degrees of extension. Of the two patients whose joint infections were treated promptly, one had full movement at eight months and the other was lost to review.

**DISCUSSION OF EXTENSION FRACTURES**

For a satisfactory result a displaced supracondylar fracture should be reduced accurately and stabilised (Mouchet 1898, Sandegard 1943, Judet 1953, Watson-Jones 1955, Gruber and Hudson 1964). Attenborough (1953) has shown that acceptance of a poor position leads to imperfect results; all four of his patients treated without reduction had limited movement of the elbow, and three also had a varus deformity. Of the common methods of treatment, a cast with the elbow in acute flexion is the most dangerous because of the risk of ischaemia and its irrevocable sequelae (MacLennan 1937, Blount 1950, Judet 1953, Böhler 1956, Fève and Judet 1957, Maylahn and Fahey 1958). If the elbow is not flexed sufficiently, however, the fracture is likely to redisplace (Swenson 1948, Judet 1953, Charnley 1961). Treatment by traction may give good results (Höyer 1952, Maylahn and Fahey 1958, Mitchell and Adams 1961, D'Ambrosia 1972) but requires a prolonged stay in hospital, constant surveillance and frequent radiographs, all of which are drawbacks in a socio-economic environment such as that of Tunisia.

These disadvantages are largely eliminated when reduction is maintained by crossed percutaneous pins. The usual technique is to place one pin laterally and the other medially, with some risk of damaging the ulnar nerve (Swenson 1948; Jones 1967; Haddad, Saer and Riordan 1970; Anderson 1971). The use of two lateral pins avoids the risk of ischaemia from acute flexion of the elbow, does not endanger any major nerve or vessel, ensures stability of the reduction and greatly reduces the time in hospital. The technique is relatively simple and easy to learn; our patients were in fact treated by no less than twenty-one doctors of varying backgrounds and levels of training. The pins penetrate the distal humeral epiphysis between trochlear and capitellum, without damaging articular cartilage. Although the fine
Kirschner wires cross the epiphysial growth plate, they do not interfere with its function (Judet 1953; Campbell, Grisolia and Zanconato 1959). Thus of our eighty patients reviewed, one developed a valgus deformity of 6 degrees over the first two years but none of the others showed any growth disturbance (Fig. 3).

The radial and median nerves and the brachial artery are particularly vulnerable in extension fractures, being at risk of stretch over the jagged edge of the shaft by the backward and upward displacement of the distal fragment and elbow (Meyerding 1936, Hammond 1952, Lipscombs and Burleson 1955, Böhler 1956, Gartland 1959, Ottolenghi 1971). The brachial artery and median nerve are injured mainly with radial displacement of the distal fragment; thus Ottolenghi (1971) reported that thirty-five of thirty-nine arterial injuries occurred with radial displacement. The radial nerve is injured mainly with medial displacement, because radial displacement pulls the nerve away from the sharp edge of the diaphyseal fracture. The ulnar nerve is rarely injured by supracondylar fractures in extension (Hammond 1952, Lichtenberg 1954, Lagrange and Rigault 1962), being relaxed and carried backward away from the fracture edge. The paper of Edman and Lörhr (1963) is unusual in reporting eleven ulnar nerve injuries in a total of twenty-seven nerve lesions among 161 patients with supracondylar fractures, but they did not differentiate between fractures in extension and in flexion. There was only one ulnar nerve lesion in our series, the girl who had temporary paralysis of all three major nerves at the elbow after the reduction.

With regard to infection, the elbow joint capsule is attached to the superior margins of the olecranon and coronoid fossae (Ashhurst 1910, Smith 1954, Gray's Anatomy 1958), and a supracondylar fracture crossing these fossae is therefore intra-articular (Hammond 1952). Hence the track of a pin crossing the fracture must communicate with the joint space. We believe that the risk of a pin track infection extending into the joint is no greater with the method we have described than with any other. The problem of infection lies in the environment rather than in the technique.

The results compare favourably with those of other series (Siris 1939, Aitken, Smith and Blackett 1943; Sandegard 1943; Holmberg 1945; Judet 1953; Lagrange and Rigault 1962; Edman and Lörhr 1963; El-Sharkawi and Fattah 1965). Seventy patients, or 87.5 per cent of those followed for more than six months, had satisfactory results. Lagrange and Rigault found that mobility of the elbow improved for two years after the fracture, but some of our patients continued to regain movement into the fourth year. Those followed for a shorter period should therefore continue to improve.

FRACTURES IN FLEXION

Clinical material—There were thirteen boys and four girls, aged from three to fourteen years. The fracture was on the left side in eleven. Based on the classification of Lagrange and Rigault (1962), three patients had Type 2 fractures with only a forward tilt of the distal fragment; three had a Type 3 fracture, the distal fragment being rotated as well as tilted forward, with only one point of contact; and eleven patients had a Type 4 fracture, with complete forward displacement and no contact (Fig. 5).

Complications of the injury—Two patients had hypoesthesia in the ulnar nerve territory; another had weakness of the interossei as well. All three lesions were associated with radial displacement of the distal fragment. There were no other nerve injuries, and no patient with symptoms or signs of vascular insufficiency.

TREATMENT

Two patients early in the series were treated by closed reduction and immobilisation for three weeks with the elbow flexed 30 degrees. Three others were treated by overhead skeletal traction using a Kirschner wire through the olecranon, two after failure of closed reduction,
the third because of gross oedema. Nine children had closed reduction and immobilisation by two lateral percutaneous pins; three were treated on the day of injury, the other six one to three days later. Reduction was performed by traction with the elbow in 45 degrees of flexion, the lateral and anterior displacement being corrected by direct digital pressure on the distal fragment. The elbow was then flexed a further 20 degrees by the assistant and two Kirschner wires were introduced lateral to the olecranon, following the technique already described. A plaster backslab was applied with the elbow at 90 degrees and the forearm in neutral rotation. Next day the cast was completed, and if the radiographs showed a satisfactory position the patient was discharged and seen at weekly intervals until the cast and pins were removed at three or four weeks.

Three patients in whom closed reduction was unsuccessful had open reduction by the Campbell posterior approach described by Boyd (1971). In two of the three the medial corner of the shaft had buttonholed the triceps postero-medially and had to be released before the fracture could be reduced; in each instance the ulnar nerve was sharply angled over the jagged edge of the shaft and required careful retraction. Complications—The only complication was one pin track infection.

RESULTS

Fifteen patients were seen on average two and a half years after the fracture, the shortest follow-up being seven months and the longest four and a half years. The results, shown in Table II, were based on the classification of Lagrange and Rigault (1962).

DISCUSSION OF FLEXION FRACUTRES

Though two types of supracondylar fracture have been recognised for many years (Malgaigne 1859, Hamilton 1880), fractures in flexion have received little attention in the past. Their incidence is reported to be 4 per cent or less of all supracondylar fractures (Mouchet 1898, Siris 1939, Blount 1954, Watson-Jones 1955, Salter 1959, Mitchell and Adams 1961, Lagrange and Rigault 1962). The high frequency in this paper, 10 per cent, is matched only by the 11 per cent of Sorrel and Sorrel-Dejerine (1938) and the 10 per cent noted by Coventry and Henderson (1956). The majority of boys over girls and of the left side over the right, however, is similar to that reported in other series (Holmberg 1945, Lipscomb and Burleson 1955, Maylahn and Fahey 1958, Lagrange and Rigault 1962, Edman and Löhr 1963).

Among the 110 patients with extension fractures reported earlier, nineteen (18 per cent) had complications involving the brachial artery, the radial nerve or the median nerve. In marked contrast, no patient with a flexion fracture had any such complication. However, three patients with flexion fractures (17 per cent) had some deficit of the ulnar nerve, compared with only one patient with an extension fracture (1 per cent). When the distal fragment is displaced anteriorly, the ulnar nerve is carried with it and may be sharply angled and stretched over the fracture margin of the shaft as this juts posteriorly. This is even more likely if the distal fragment is also displaced radially, as then the ulnar nerve is pulled laterally across.
TABLE II
DETAILS OF SEVENTEEN CHILDREN WITH DISPLACED SUPRACONDYLAR FLEXION FRACTURES OF THE ELBOW

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years)</th>
<th>Type of fracture</th>
<th>Complications</th>
<th>Treatment</th>
<th>Length of follow-up (months)</th>
<th>Range of movement (normal side in brackets) (degrees)</th>
<th>Change in carrying angle (degrees)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>8</td>
<td>4</td>
<td></td>
<td>Cast in extension</td>
<td>54</td>
<td>0-95 (0-150)</td>
<td>Lost 12</td>
<td>Poor</td>
</tr>
<tr>
<td>Male</td>
<td>9</td>
<td>4</td>
<td></td>
<td>Cast in extension</td>
<td>39</td>
<td>0-120 (0-150)</td>
<td>Lost 2</td>
<td>Fair</td>
</tr>
<tr>
<td>Male</td>
<td>4</td>
<td>4</td>
<td></td>
<td>Failed manipulation, traction</td>
<td>24</td>
<td>0-135 (0-145)</td>
<td>Lost 4</td>
<td>Fair</td>
</tr>
<tr>
<td>Male</td>
<td>11</td>
<td>3</td>
<td></td>
<td>Ulnar nerve hypoaeesthesia</td>
<td>Failed manipulation, traction</td>
<td>10-110 (0-145)</td>
<td>Varus 15</td>
<td>Poor</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>4</td>
<td></td>
<td>Traction</td>
<td>Did not return</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
<td>4</td>
<td></td>
<td>Closed reduction and pins</td>
<td>7</td>
<td>0-140 (0-140)</td>
<td>No change</td>
<td>Excellent</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>4</td>
<td></td>
<td>Closed reduction and pins</td>
<td>Did not return</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13</td>
<td>2</td>
<td></td>
<td>Closed reduction and pins</td>
<td>26</td>
<td>5-140 (0-155)</td>
<td>Lost 4</td>
<td>Fair</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>3</td>
<td></td>
<td>Closed reduction and pins</td>
<td>10</td>
<td>0-145 (0-145)</td>
<td>No change</td>
<td>Excellent</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>2</td>
<td></td>
<td>Closed reduction and pins</td>
<td>26</td>
<td>0-160 (0-160)</td>
<td>Lost 2</td>
<td>Good</td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
<td>4</td>
<td></td>
<td>Closed reduction and pins</td>
<td>41</td>
<td>0-150 (0-150)</td>
<td>No change</td>
<td>Excellent</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>4</td>
<td></td>
<td>Pin track infection</td>
<td>Closed reduction and pins</td>
<td>22</td>
<td>5-125 (0-145)</td>
<td>No change</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>3</td>
<td></td>
<td>Closed reduction and pins</td>
<td>43</td>
<td>0-155 (0-160)</td>
<td>Lost 10</td>
<td>Fair</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>2</td>
<td></td>
<td>Ulnar nerve hypoaeesthesia</td>
<td>Closed reduction and pins</td>
<td>44</td>
<td>0-145 (0-140)</td>
<td>Lost 3</td>
</tr>
<tr>
<td>Male</td>
<td>14</td>
<td>4</td>
<td></td>
<td>Open reduction</td>
<td>18</td>
<td>25-135 (0-145)</td>
<td></td>
<td>Fair</td>
</tr>
<tr>
<td>Male</td>
<td>14</td>
<td>4</td>
<td></td>
<td>Ulnar nerve hypoaeesthesia and weakness of interossei</td>
<td>Open reduction</td>
<td>12</td>
<td>0-145 (0-145)</td>
<td>No change</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>4</td>
<td></td>
<td>Open reduction</td>
<td>48</td>
<td>0-140 (0-140)</td>
<td>Lost 4</td>
<td>Good</td>
</tr>
</tbody>
</table>

the shaft and cannot escape it. The vessels and nerves in front of the elbow, on the other hand, are carried forward and upward away from the shaft and are therefore less vulnerable. This reaffirms previous observations (Sorrel and Sorrel-Dejerine 1938, Hammond 1952, Smith 1954, Lipscomb and Burleson 1955, Böhler 1956).

Sorrel and Sorrel-Dejerine recommended surgical exploration and release of an injured ulnar nerve if there were no signs of recovery by ten or fifteen days. Hammond stated that six weeks was the optimum period to wait before exploring the nerve. Seddon (1947) believed
that nerve damage requiring exploration was rare. Corresponding with our experience of nerve injuries associated with extension fractures, these three patients with ulnar nerve lesions fully recovered spontaneously.

There was no correlation between the original displacement of the flexion fractures and the functional or anatomical results. Both patients who were treated with the elbow in some flexion finally lacked a significant degree of flexion, and one had a varus deformity. Of the three patients treated by traction, two were seen at follow-up and both had unsatisfactory results (Table II). When the method of treatment already used for extension fractures was adopted, the increased difficulties of reduction, and of maintenance of reduction while introducing the pins, soon became apparent. As in the experience of Siris (1939), closed reduction failed in one-third of our patients, compared with only twice in 112 extension fractures. The difficulty arises because, in reducing the anterior displacement, the distal fragment is often flexed by the shaft rather than engaged with its fractured surface, and it is difficult to gain a purchase on the small fragment and avoid this. Moreover, the fracture line is oblique in an upward and forward direction, and reduction may easily be lost.

Of the fifteen patients reviewed, only seven had satisfactory results. Of four children seen at follow-up who had been treated by traction, or by plaster with the elbow in moderate extension, the outcome was satisfactory in none, two being fair and two poor. Five of eight patients treated by closed reduction and percutaneous pins were excellent or good and three were fair; these results are disappointing compared with those obtained from extension fractures. Open reduction of a supracondylar fracture may leave the patient with some limitation of movement (Sandegard 1943, Blount 1954, Watson-Jones 1955, Gruber and Hudson 1964), as was the case with one of the three patients in this series. Nevertheless, these patients still had better results than those treated by traction or an extension cast alone, and we therefore prefer open reduction if closed manipulation fails.

SUMMARY

Displaced extension supracondylar fractures of the elbow
1. One hundred and ten children were treated by reduction and stabilisation by two pins inserted laterally at an angle of 30 degrees to one another.
2. The complications before and after treatment included fifteen nerve lesions in thirteen patients. The ulnar nerve was involved on one occasion only. Solitary radial nerve injuries occurred with posterior-medial displacement of the distal fragment, while median nerve and brachial artery injuries were associated with posterior-lateral displacement. All the lesions recovered spontaneously.
3. There were no ischaemic complications after treatment, despite the ligation of one ruptured brachial artery.
4. The average stay in hospital was four days, compared with twenty days for thirty-two other patients treated in traction because of gross oedema.
5. Of eighty patients seen six months to five years after the fracture, seventy (or 87·5 per cent) had excellent or good results, seven patients with marked varus deformities had fair results, and two patients had poor results with very stiff elbows.

Displaced flexion fractures
1. The clinical features, complications and treatment of seventeen cases are described.
2. There were no complications involving the median or radial nerves or the brachial artery, but three patients had a lesion of the ulnar nerve.
3. Nine children had closed reduction and fixation by two lateral percutaneous pins.
4. Reduction was difficult and the results poor compared with extension fractures. Closed reduction failed in one-third of the children, and the functional and cosmetic results were unsatisfactory in over half the patients reviewed.
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