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ORIGINAL ARTICLE

Functioning Free Gracilis Muscle Transfer for Restoration of Elbow Flexion in Adult Brachial Plexus Palsy - The Ganga Hospital Approach

Hari Venkatramani[1], Praveen Bhardwaj[2], S Raja Sabapathy[3]

Introduction

Global brachial plexus injury is a devastating injury and restitution of all functions is seldom possible. If the patient presents late, the few available options of early nerve surgery also become not applicable. In such situations functioning free muscle transfer may become the only option to restore some function. Functioning Free Muscle Transfer (FFMT) is a procedure in which a healthy muscle along with its vascular pedicle and motor nerve is harvested from a distant site and transferred to restore the lost function in a limb. Various workers in the field have established the order of priority in restoration of function and all stress the importance of elbow flexion as the primary step. Different strategies have been popularized by Barrie et al[1], Doi[2,3], Chuang[4], and Levin et al[5]. All of them performed FFMT for elbow flexion and this was combined with some other nerve transfer or another FFMT for finger flexion. Doi proposed FFMT as the primary procedure even when the patient is seen early[3]. Doi used a FFMT for elbow flexion and extended it to gain finger extension in stage one and performed a second FFMT for elbow extension and finger flexion at the second stage 6 months after the first FFMT. Chuang carried out nerve transfer for proximal function and finally FFMT for finger function[6]. The Mayo clinic surgeons found that when they used a FFMT to obtain both elbow flexion and finger extension the outcome was suboptimal and they have come to prefer to use one muscle for one function[7].

✉ Hari Venkatramani
Mobile: +91 9842202422
Email: drhariv@gmail.com

1 Senior Consultant, Department of Hand and Reconstructive surgery, No. 313, Mettupalayam Road, Saibaba Koil, Coimbatore, Tamil Nadu 641043

2 Consultant, Department of Hand and Reconstructive surgery, Coimbatore, Tamil Nadu

3 Senior Consultant and Director, Department of Hand and Reconstructive surgery, Coimbatore, Tamil Nadu

In adult global brachial plexus palsy FFMT is used to restore function,

A. following suboptimal spontaneous recovery.

B. when the injury - presentation interval is beyond 9 months.

C. when poor recovery is obtained following attempted nerve reconstruction.

Ganga Hospital Experience with FFMT in Global Brachial Plexus Palsy

The Ganga Hospital protocol for patients with adult brachial plexus palsy seen either late (more than 1 year) or where we failed to obtain adequate results after nerve transfer, is to first carry out a FFMT for elbow flexion. When we obtain Grade 4 power of elbow flexion following the FFMT, the wrist and the first carpo-metacarpal joints are fused. This usually occurs around 9 to 12 months after the FFMT procedure. The fusion of the wrist and the first CMC joint makes the part of the limb distal to the elbow function as a single unit during elbow flexion. Addosooki et al., found improved DASH score after wrist arthrodesis[8]. The wrist is arthrodesed in neutral position with the forearm in mid prone position and the first CMC joint with the thumb in full abduction and in line with the radial border of the index finger. With the wrist no longer dropping during the attempted flexion of the elbow, the patient finds elbow flexion easier. Ease of performance makes them attempt flexion of the elbow more often, there by strengthening the power of the transferred muscle. When the options for extensor reconstruction do not exist or are difficult to achieve and only finger flexors are to be reconstructed it is better to have the wrist in neutral position than in extension. This will help in greater arc of release of the fingers when the reconstructed flexors relax. As the third step, a second FFMT is carried out to gain finger flexion, 4-6 months after wrist fusion to obtain a hook grip. Spinal Accessory nerve is used as the donor nerve for the first FFMT and 3,4, 5 intercostal nerves are used to motor the second FFMT.

Selection of Appropriate Donor Muscle

The common choice of donor muscles for FFMT are the gracilis, rectus femoris and latissimus dorsi. Latissimus dorsi and rectus femoris, by virtue of their size and higher cross section, can provide more power following transfer during restoration of elbow flexion. Gracilis, by virtue of its longer length of muscle fibres has longer excursion, and so is better suited for restoring finger flexion.

We have used gracilis exclusively as a donor muscle in over 125 cases of FFMT in upper limb. Of these 97 have been for brachial plexus reconstruction.

- restoration of elbow flexion in 80
- restoration of finger flexion in 17

Most of our patients are reluctant to have latissimus dorsi harvested from the uninvolved opposite limb. Hence our experience in using FFMT in brachial plexus patients is restricted to the use of the gracilis and it will be presented in greater detail. Terzis and Kostopaulos in a series of 73 cases found comparable outcome following latissimus dorsi and gracilis, when used for restoration of elbow flexion[9].

Gracilis as a Donor Muscle for FFMT

Gracilis is a strap muscle with a mean muscle belly length of 26 cm (total with tendon 38- 40 cm) and has an excursion of 10 cm. The muscle has constant vascular and nerve anatomy with no difficult variations. The length of the vascular pedicle is 6 to 8 cm. The obturator nerve is harvested by dissecting proximally as far as possible and a length of about 10 cm can be obtained. This step is important since direct repair of the nerve is mandatory in FFMT and in brachial plexus patients associated with vascular injury or extensive fibrosis having a long length of nerve will be helpful in reaching out to a better choice of vascular pedicle. We have obtained 74% M4 results in 60 patients wherein gracilis was used to gain elbow flexion, at 2 year follow-up. Barrie et al[1] reported 79% and 63% M4 or more outcome following single and double muscle transfer respectively.

Surgical Technique

Performing a free muscle flap for function differs from doing a free muscle flap for cover in the following ways. First we may encounter more unexpected findings in FFMT patients like severe fibrosis of structures surrounding the vascular pedicles and nerves, poor flow in the donor vascular pedicle or poor quality of the donor nerve. Planning and executing the inset of the flap is important so that the nerves can be approximated with no tension after the anastomosis of the vascular pedicle. In that setting the muscle must be inset in such a way that it is in direct line of the proposed function. In these aspects performing an FFMT is technically more demanding than doing a free muscle flap for cover. It is important to keep the ischemia time to the minimum. Ideally this should be between 90-120 minutes for better preservation of muscle fibres. Blaisdell found irreversible damage to the muscle after 4-6 hours of ischemia time[10]. Muscle that has been ischemic for longer than 4 hours is, therefore, unlikely to be functional even following reinnervation. So before dividing the vascular pedicle at the donor site, everything in the recipient area is kept ready.

Neurovascular Donors

When gracilis is used as a donor muscle for FFMT for elbow flexion, we have encountered the following 3 situations and our reconstruction strategy is as follows.

1. In Global Brachial Plexus Palsy
   - Donor nerve: Spinal Accessory nerve (SA)
   - Donor vessels: Thoracoacromial artery (TA)
   - Proximal attachment: Clavicle

Technique: The neck is explored through a transverse skin crease incision 2 cm above the clavicle as for a standard brachial plexus exploration. The anterior border of the trapezius muscle is identified and the spinal accessory is dissected out by identifying the nerve on the inner aspect of the muscle about 2 to 3 cm from the anterior border. This is kept safe in a loop. The medial arm incision is extended along the roof of the axilla and along the pectoralis major up to the clavicle. The two parts of pectoralis major are split along the gray line separating the clavicular and sternal parts. The pectoralis minor is then visualized and divided close to its insertion. Along the medial border of pectoralis minor the thoracoacromial artery is seen emerging from the first part of the axillary artery. It is dissected out and prepared for anastomosis. If an additional vein is needed, the cephalic vein is dissected, mobilized closer to the thoracoacromial artery from its position in the deltopectoral groove. There is a good size match between the vessels of the thoracoacromial trunk and gracilis vascular pedicle (Fig 1 a to c). The gracilis comes to lie along the line of the biceps when it is attached to the clavicle proximally. The fixation to the clavicle is done by drilling two holes with 1.5mm k-wire and passing PDS-2 (polydioaxanone) suture through these holes. The suture is held in a haemostat and kept ready. The gracilis after harvest is brought to

the neck and the proximal edge is attached to the clavicle by passing these 2 sutures into it (Fig 2 a to c). Distally the gracilis tendon is anchored to the biceps tendon.

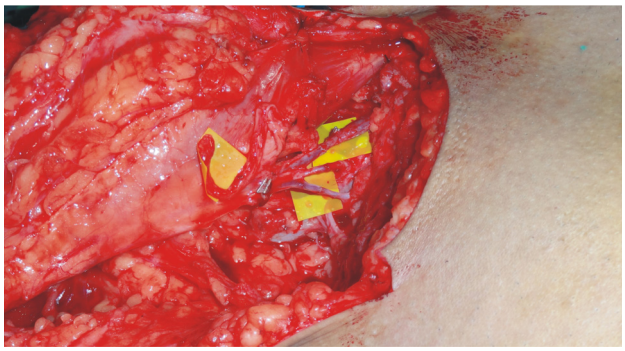

Fig. 1 (a) Vascular anastomosis between the thoracoacromial trunk and the gracilis pedicle.

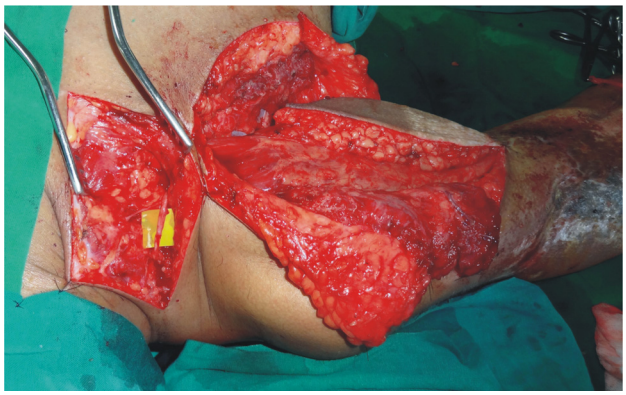

Fig. 1 (b) Nerve co-aptation between the obturator and Spinal accessory nerves.

Fig. 1 (c) Post op result at 1 year follow-up

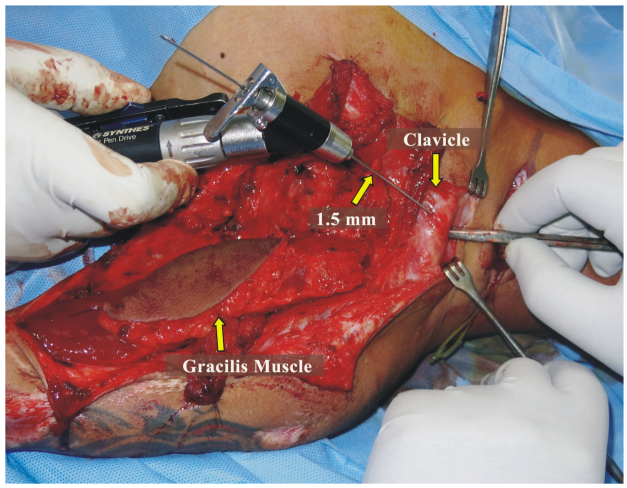

Fig. 2 (a) Pilot holes being drilled in the clavicle with a 1.5 mm k wire.

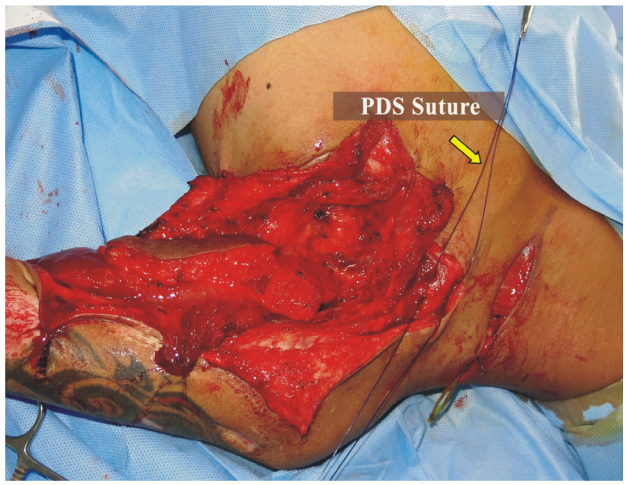

Fig. 2 (b) PDS sutures being passed through the clavicle.

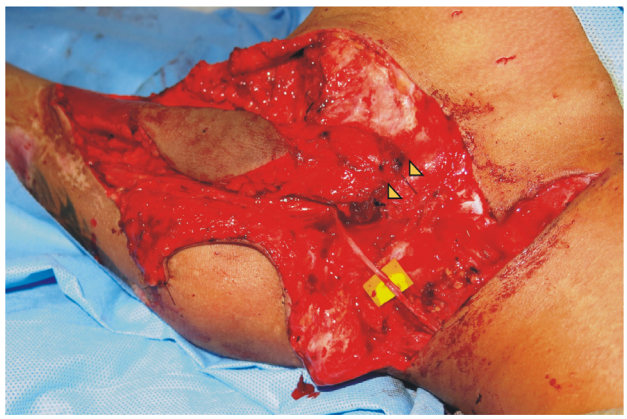

Fig. 2 (c) Gracilis fixed to clavicle. Yellow arrowheads show the sutures. Nerve coaptation to spinal accessory also completed.

2. In global brachial plexus palsy when the spinal accessory nerve is not available,
   - Donor nerves:3, 4 &5 Intercostal nerves (ICN)
   - Donor vessels :Thoracodorsal artery (TD)
   - Proximal attachment: 2nd rib or coracoid process.

The contralateral gracilis is preferred in this situation, as the pedicle and nerve face the donor nerves and vessel comfortably. We prefer to use the 3,4 and 5 intercostal nerves (Fig. 3a to c).

3. Failed recovery or delayed presentation following C5, 6 &7 palsy (Fig 4)
   - Donor nerve: Fascicle of median or ulnar nerves
   - Donor vessels: Thoracodorsal artery (TD) or end to side attachment to the brachial artery, with cephalic vein
   - Proximal attachment: Coracoid Process

Fig. 3 (a) Right sided global palsy,with failed spinal accessory to musculocutaneous nerve transfer.

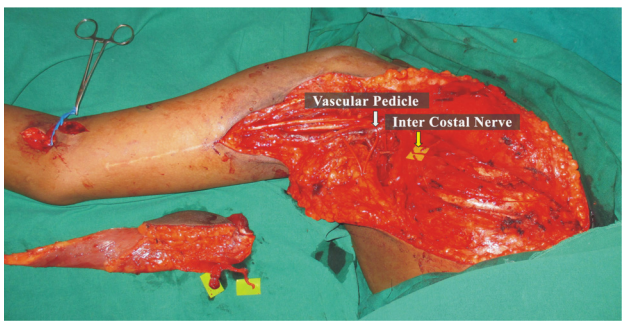

Fig. 3 (b) Gracilis seen along with the vascular pedicle and intercostal nerve.

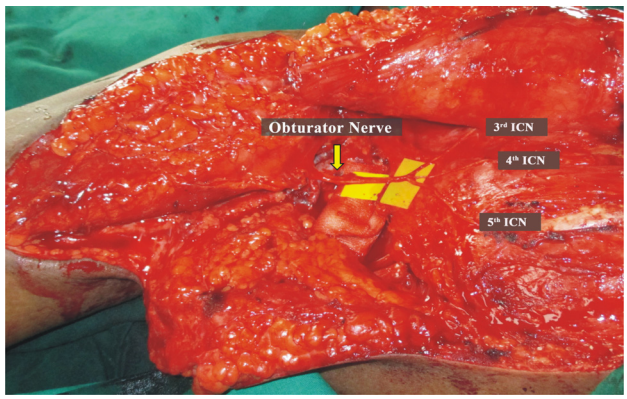

Fig. 3 (c) Nerve co-aptation between Obturator and 3,4&5 ICN

Fig. 3 (d) 18 month post operative showing MRC Grade 4 outcome

Fig. 4 (a) Left sided upper brachial plexus palsy

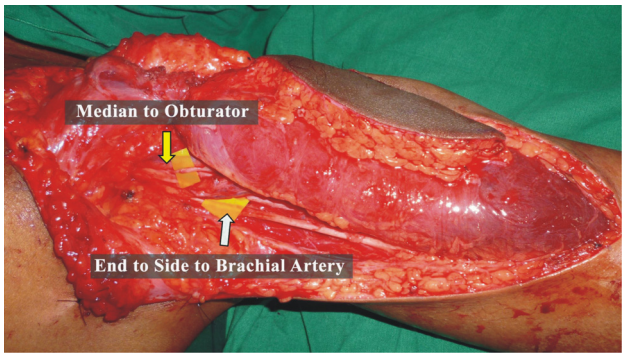

Fig. 4 (b) Fixation of gracilis to coracoid process, nerve co-aptation with median nerve and vascular anastomosis with brachial artery

Fig. 4 (c) Postoperative result showing grade 4 outcome.

Flap harvest: Gracilis flap harvest can be performed simultaneously along with the neck exploration. The thigh is kept flexed to 30 degrees, and externally rotated. The adductor longus muscle becomes taut and felt easily and the gracilis lies along a line 2 finger breadths below and parallel to the adductor longus [Fig. 5a]. We prefer to incorporate a skin island and it has the following advantages:

1. It is useful for post-operative with flap monitoring and as a site for post-operative electrical stimulation.
2. It prevents tight skin closure along the axilla.

Many believe that the skin island is not reliable, but our experience has been otherwise. It should be sited along the septum between adductor longus and gracilis in the upper third of the muscle as the main blood supply to the skin island comes from septocutaneous perforators in this region [Fig. 5b][11]. A sleeve of fatty tissue over the epimysium of gracilis is retained to avoid exposing any muscle fibers. It also prevents muscle adherence to the bed, providing a good gliding surface. The exact length of muscle required from the desired proximal attachment to the biceps tendon in the elbow is accurately measured [Fig. 5c]. In a healthy adult gracilis resting length is 26 cm. On stimulation the muscle contracts and reduces in length up to 40% of resting length[7].

The side of the harvest depends upon the location and lie of donor vessels. If the vascular pedicle used as recipient is the thoracoacromial axis, the contralateral gracilis is harvested. If brachial artery is going to be the recipient, the ipsilateral side is preferred.

The length of the muscle is a near exact match for the biceps length defect and thus is always kept in its original tension. Hence, marking the muscle at regular intervals is ideal[12]. Since the muscle belly is tunneled to its new insertion very little of the muscle belly is visible after the transfer process. Therefore, it is important to have a feel of the resting length of the muscle and tension before complete dissection and division. The distal anchoring is done with a Pulvertaft weave using 2-0 Ethibond (braided nylon) or Prolene keeping the elbow in 100 degrees of flexion and forearm fully supinated. Every attempt is made to harvest the maximum length of the pedicle and the obturator nerve is followed as proximally as possible.

Fig. 5 (a) Skin marking showing straight line overlying adductor longus and the skin island.

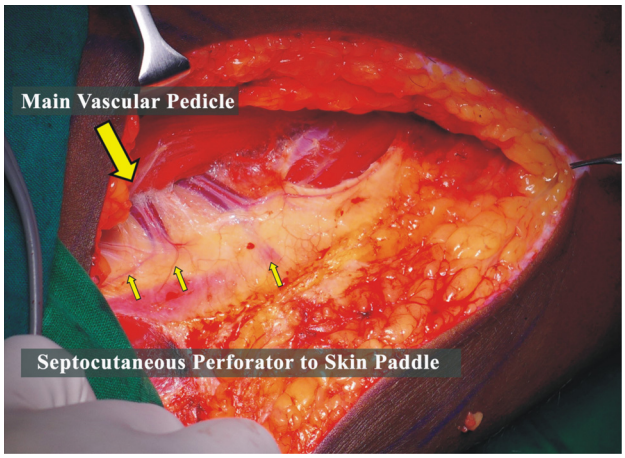

Fig. 5 (b) Bold arrow pointing to main vascular pedicle and multiple small arrows along the septo-cutaneous perforators

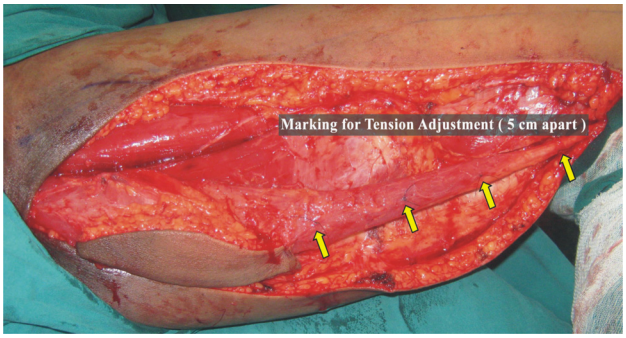

Fig. 5 (c) Gracilis before dividing, arrow marks along the muscle at constant distance of 5 cm for adjusting tension.

Vascular Anastomosis and Nerve Coaptation

Adequate length of vascular pedicle is very important especially when planning to perform an end to side anastomosis. A tension-free repair should be done whilst maintaining reasonable tension in the muscle. It is important that thorough preparation of donor vessels and stay sutures for anchoring the muscle to the bone proximally are all carried out before dividing the gracilis pedicle, in order to minimise the ischaemia time to below 90 min.

The nerve coaptation is carried out after the second vein anastomosis and we always prefer to use 10-0 nylon for nerve repair. Additionally, fibrin glue is used in intercostal nerve coaptation and in children for extra safety at the repair site. At the end of the vascular anastomosis many a time we have observed fresh bleeding at the cut end of the obturator nerve. If the ischaemia time is kept below 90-120 min, the nerve on handling will cause twitching of the muscle at the time of repair. That is a reassuring sign of potential for function if nerve recovery occurs. After the vessels and nerve are repaired, the muscle tension is adjusted to its original resting length. At this time the muscle is pulled to its original length. While doing this final adjustment of muscle tension one must all the time inspect the anastomosis site for any pull or twist of pedicle. Once the repair site is seen and the lie of vessels is confirmed to be good, a few anchoring sutures between the skin island and wound margin are taken to maintain the position. The distal gracilis tendon to biceps tendon fixation is the final step before skin closure over a drain.

Post Operative Monitoring and Positioning of the Limb

The flap is monitored post operatively by hourly scratching of the skin island with a No. 22 disposable needle for the first 6 hrs and then two hourly for the next 24 hours. The patient is shifted from the microsurgical ICU on the third post-operative day after removal of the drain and the urinary catheter. Intravenous infusion of Heparin (5000 units in 500mls of normal saline) over 24 hours is continued for 5 days.

The shoulder is kept at 60 degrees of abduction and elbow is maintained at 100 degrees of flexion. A plaster splint is applied to maintain the position and retained for 10 days when the sutures are removed. A detachable splint is made to maintain the same position for 4 weeks. After 4 weeks the splint is removed and an above elbow detachable thermoplastic splint with 100 degrees of elbow flexion is applied. Galvanic stimulation is started at 4 weeks in short cycles and continued till active flexion is regained. All patients are sent home with a nerve stimulator machine with instructions to carry out electrical stimulation by the patient or the members of the family. They are discharged when they are comfortable with all post-operative physiotherapy protocols.

The first signs of recovery are seen at 6months on average and Grade 3 power is reached by 12 months in successful cases. At our centre, 44 of 60patients obtained Grade 4 elbow flexion at 2 years.

Complications

With improved microsurgical expertise the incidence of total flap loss following vascular compromise is low. We had two flap losses in 125 cases of FFMT (1.6%). Strict flap monitoring in the first 48 hours is crucial. Skin paddle necrosis has also been minimized with better understanding of the blood supply of the skin

island by placing it anterior to the line of the muscle over the septum between the adductor longus and the gracilis. We had complications in the survival of the skin flap in 3 patients with survival of the muscle. Haematoma or seroma can happen because of extensive dissection along the axilla and medial arm. Meticulous attention to haemostasis is important and we practice liberal use of corrugated drains. Donor site wound dehiscence in an obese patient should be kept in mind when skin island is harvested. Layered closure with closed suction drains after thorough haemostasis reduces wound complications.

Outcome Measures

The functional outcome following FFMT for elbow flexion is assessed usually by a scale proposed by Doi:[13]

M0 - no contraction

M1 - no joint movement but electromyographic innervation seen

M2 - active movement seen, but not against gravity

M3 - sufficient power to act against gravity, with more than 30 degrees of flexion

M4 - muscle acts against some resistance, flexion range more than 60 degrees

M5 - muscle acts against strong resistance, flexion range more than 90 degrees

Conclusions

Functioning free gracilis muscle for the restoration of elbow flexion is a very rewarding procedure and many times may be the only procedure possible. Attention to detail in every step of the surgery is important, the key step being the minimizing the flap ischaemia time. The final outcome depends on good technique, the quality of the donor nerve and post-operative physiotherapy. Gracilis is the flap of choice for FFMT because of its anatomical features. Wider usage and long term follow-up from many units will reduce the threshold for usage of FFMT and benefit more number of patients.

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