CURRENT CONCEPTS REVIEW/SOUBORNÝ REFERÁT

Surgical Treatment of Wrist and Hand Deformity in Children with Cerebral Palsy

Chirurgická léčba deformity zápěstí a ruky u dětí s dětskou mozkovou obrnou

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SUMMARY

Cerebral palsy (CP) is a complex disorder resulting from injury to developing brain. It involves multimodal and multidisciplinary approach that involves various disciplines of medical science. The entire focus of this approach is to provide patients with this disorder the best quality of life. Although CP can affect both upper and lower limbs, the functional expectation of upper limb is much higher and complex. This implies particularly to hand and wrist based on complex functional movements expected of them. This puts orthopaedic surgeons in a unique position in managing these patients. It is worth mentioning here that it is not about offering them a surgical intervention the emphasis should lie on the entire process of selection, evaluation, and intervention. All these steps need to be considered very thoroughly so that the best outcome is achieved based on patients' expectation at present and keeping the future consideration in mind as well.

This paper focuses only on children with hand and wrist deformity. Although children have a great healing potential, but they have high functional demand and longer-life expectancy in general so getting things right for the first time should be of paramount importance. This paper tries to address this issue by reviewing the literature to help orthopaedic surgeons in developing an algorithm in their mind when offering intervention. The consideration of inclusion and exclusion criteria along with review of literature has been considered with this background in mind. This paper primarily addresses the surgical aspect of disease and steps that are critical in this regard. Follow up planning, long-term outcome, rehabilitation planning, use of conservative treatment has not been considered in this review.

Key words: wrist and hand deformity, surgical teatment, children, cerebral palsy.

INTRODUCTION

Cerebral palsy (CP) is complex disorder that involves multimodel and multidisciplinary approach. Surgical treatment is more dedicated to spastic type of deformity. Spastic deformity is explained as velocity dependent increase in tone and hyperreflexia. In terms of motor forms of disease, it can be spastic, athetoid or flaccid. Biomechanically spastic disorders are result of flaccidity of its antagonist muscle counterpart. In terms of its implication regarding surgical intervention, release of antagonist muscle along with muscle transfer to restore function and fine balance is one of the goals of treatment. The manifestation of CP in terms of hand function is manifested as absence of key pinch around 1 year of age (2).

Wrist and hand are essential in maintaining function of upper extremity for grasp, pinch, and release activities. The upper extremity classically assumes flexed wrist, thumb in palm and flexed finger posture. These functions are affected to a variable extend and can affect activities of daily routine like hygiene, hand grip along with cosmetic disfigurement. Wrist flexion makes function of fingers and hand limited leading to poor quality of life. Moreover, flexed wrist points to a marked cosmetic deformity as well and can leads to social stigma and poor self-esteem for the child. In ideal circumstances the

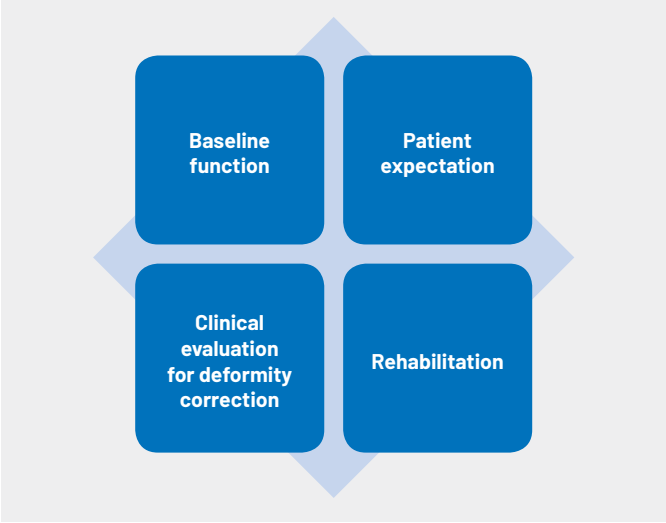

Fig. 1. **Pillars of assessment.**

wrist flexors tend to relax when finger flexors are activated along with activation of wrist extensors that helps in providing the necessary hand grip (5).

This systemic review is chiefly concerned with improvement in function of hand and wrist. However, in terms of offering anything substantive or to plan operative management an assessment of whole upper limb is of paramount importance (8). The process of evaluation and management which will be considered in this review are summarized in Figure 1.

In our opinion the more thoroughly these steps are reviewed it is likely that patients and care givers will have an improved functional outcome. The following sections of paper will try to elaborate this process to improve patient related outcomes and evidence around decision making process for surgeons.

Aims and objectives

The aim of this study is to present with findings associated with clinical features and management of hand and wrist deformity in children with cerebral palsy. The concept of this paper lies on the idea to discuss the entire patient pathway and explain the decision-making process that is involved in offering these patients with any type of surgical intervention to improve outcome.

Methodology

A search of literature in Medline and PubMed was made using the following phrase "Treatment of hand deformity in patient with cerebral palsy".

This revealed a total of 127 results. Following inclusion and exclusion criteria the number of papers were narrowed down to 10. After discussion with the authors following inclusion and exclusion criteria was agreed upon:

Inclusion criteria

1. Articles reviewing cerebral palsy associated deformities of hand and wrist in patients up to 16 years of age.
2. Articles discussing deformity of hands and wrist specifically associated with cerebral palsy and surgical treatment options.
3. Relevant clinical findings and decision-making progress for surgical intervention in CP.
4. Tendon transfer options for patient with hand and wrist deformities in cerebral palsy. (Figure 2).

Exclusion criteria

1. Use of conservative treatment and follow up following intervention (37).
2. Articles dealing with deformities other than hand and wrist (23).

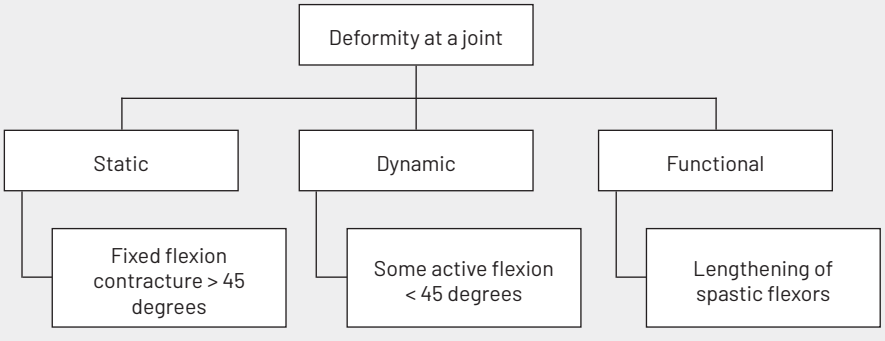

Fig. 2. **Inclusion and exclusion of included articles.**

3. Articles not in English (18).
4. Papers dealing with neurological disorder in adults and adults and children (16).
5. Complete articles were not accessible (2) or discussing deformities not affiliated with cerebral palsy (9).
6. Paper primarily discussing rehabilitation protocols and cerebral palsy in general (9).
7. Case report comprising of less than 5 cases (3).

Papers under review were broadly classified into two categories:
1. Papers dealing with principles of deformity correction especially involving the wrist and hand (7).
2. Paper dealing with hand deformity only (3).

Although this division is to make it review more systemic and make it more readable for the reader, but there is likely to be considerable overlap between the two broad categories that were created in this review.

LITERATURE REVIEW

1. **Principles of surgery**
   In terms of options for intervention they can be broadly divided into 4 categories:
- Musculotendinous units can be either be released and lengthened.
- Tenodesed
- Transferred or rerouted
- Arthrodesis of joint (2)

In terms of intervention, it is worth mentioning here that intervention at one level can lead to worsening of deformity at the other level. For example, correction of flexion contracture of wrist can lead to worsening deformity of fingers. This signifies complete assessment of extremity.

Surgical interventions are usually done between 3 to 6 years of age. However, there is some evidence of intervention around 2 years to have better cortical imprint and avoid neglect in terms of use of extremity (2).

2. **Clinical examination**
   Clinical assessment of wrist and hand, the deformity is usually associated with weak extensor, tight flexors or due to tight wrist capsule. Voluntary hand movements are the best predictor of hand function post operatively. The deformity can be classified into three broad categories which helps in proceeding with type of procedure that can be offered to patients (2). (Fig. 3). Fixed deformities are treated with fusion, functional deformity with tendon lengthening and dynamic with tendon transfer. In terms of assessment of individual hand functional muscle (2).
- FCU (*flexor carpi ulnaris*), FCR (*flexor carpi radialis*) palpate by active wrist flexion (2).
- ECU (*extensor capri ulnaris*), ECRB (*extensor carpi radialis*), ECRL (*extensor carpi radialis longus*) can be assessed by wrist extension. In terms of ECU assess with ulnar deviation and wrist extension (2).

Finger examination involves assessment of active movements at wrist along with movements of fingers. In terms of deformity of fingers, they can be divided into 2 broad categories:

I. Flexion deformity resulting from tight flexors or weak extensors.
II. Hyperextension deformity resulting at the PIPJ (Proximal Interphalangeal Joint) causing Swan Neck deformity. The aetiology of Swan neck can be explained based on loss of balance between PIPJ hyperextension and DIPJ (Distal Interphalangeal Joint) flexion. Intrinsic muscle over pulls lateral band leading to PIPJ extension. In chronic cases there is loss of function of transverse retinacular ligament, over stretching of volar plate leading to dorsal subluxation of lateral band (2, 8).

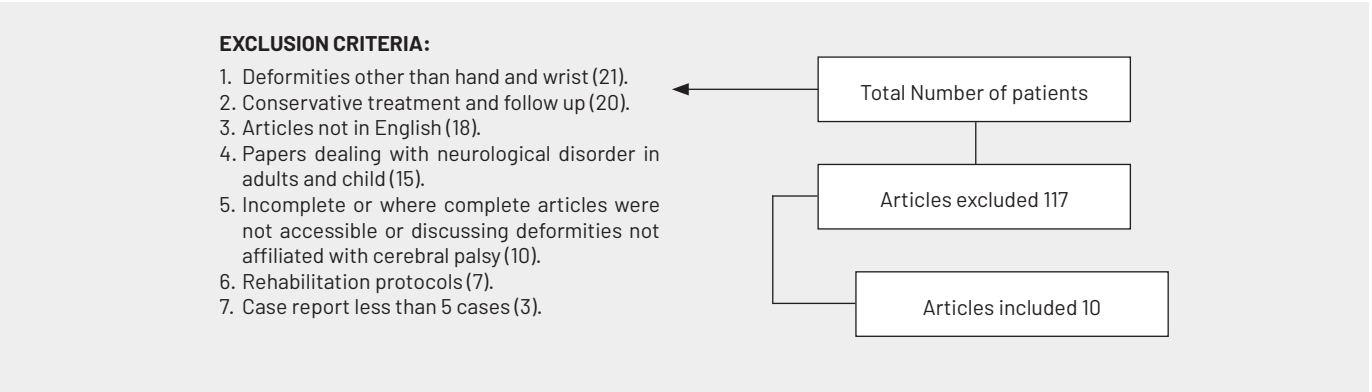

Fig. 3. **Types of joint deformity.**

Quality of skin, pliability, previous scar and identification of tight tendon units can be assessed on clinical examination. Radiographs helps to identify any long-term changes in the joints involved as well as assessment of height of proximal row of carpal bones. Zancolli classification system can be used to explain the deformity of hand and wrist (5, 8).

- Thumb deformity

Position of thumb should be assessed at two key positions:

I. Position of thumb in fisting.
II. Inability to extend the thumb out of palm with loss of first web space. In terms of assessment of thumb function assessment of thumb position in pronation position of forearm helps to make assessment as well. EPL (*extensor pollics longus*) EPB (*extensor pollics brevis*) tendon work as a synchronous muscle with extension and abduction. Lack of firing of EPB results in adducted position of thumb. Abductor pollics longus has little contribution in actual thumb abduction. Adductor pollics and first dorsal interosseous contribute to adduction deformity (2).

3. **Surgical treatment**
   The indication of surgical intervention cannot be defined alone on degree of deformity. Having said that mild deformities can be addressed with conservative treatment in terms of splinting and botulism toxin injections. The recommended indication of surgery involves failure to perform pinch grip and struggling to perform activities of daily living like hygiene, eating and drinking. Another agreed indication of surgery involves ulceration of the palm and skin problems associated with deformity (5).

In absence of wrist flexor tendon co-contraction lengthening of tendons can be an option to restore the tendon length. This can be used principally where the extensor tendons are functional and only there is contracture of flexor tendons. Volkman angle can give us a rough guide in terms of assessment of deformity. Based on degree of release required small deformities can be corrected with fractional lengthening and large corrections will require Z step lengthening. The idea was to weaken the flexors so that balance can be restored between the flexors and extensors (5, 8).

In short, a step wise evaluation and intervention can be considered both pre-op and intra-op starting from simple releases of musculotendinous units to tendon transfer to improvement in function. Arthrodesis is considered as a last resort for static deformation where stabilization of joint is deemed necessary (8).

General assessment of tendon transfer should be kept in mind when offering or considering tendon transfer. The factors can be broadly divided into patient factors and transfer factors. Ideally a sensible patient that is compliant with rehabilitation protocol. Following principles should be considered:

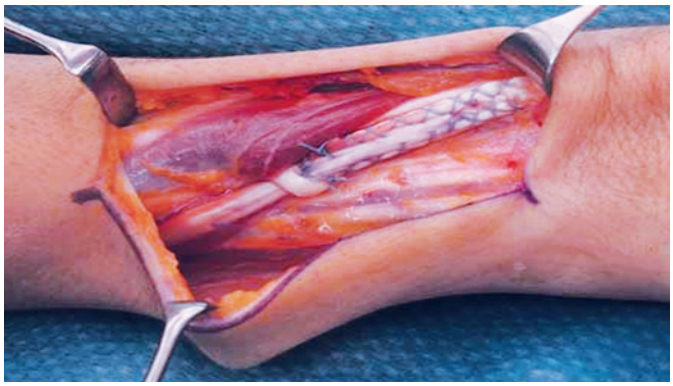

Fig. 4. **Transfer of FCU to FCRB to balance the wrist.**

Reference: Schibli S, Fridén J. Rebalancing the spastic wrist by transposition of antagonistic muscle-tendon complex. Tech Hand Up Extrem Surg. 2022;26:127–130. doi: 10.1097/BTH.0000000000000371.

1. Match donor and recipient work capacity.
2. Excursion.
3. Synergy of tendon function.
4. Straight line of pull to improve tendon function.
5. Single donor function.
6. Supple joint and minimum morbidity at donor and recipient site (7).

Dynamic deformity correction

Tendon transfer options

Option 1: FCU – ECRB: (*flexor carpi ulnaris* to *extensor carpi radialis brevis*)

It is the first choice in terms of tendon transfer. Pulvertaft weaver FCU to ECRB (Fig. 4) and at the end of transfer should be in 20 degrees of flexion in pronation when hand is lifted off the table in pronation (2). In case this option is not available then proceed with 2nd option. This was the original transfer described by Green as well. The drawback in this case that it can lead to overcorrection in a young child or in children with mild deformity. In terms of FCU to ECRB will lead to more central action of wrist dorsiflexion compared to FCU to ECRL (*extensor carpi radialis longus*). This ECRL transfer will lead to more radial pull and thus help in correction of ulnar deviation (2, 8)

Option 2: ECU – ECRB: (*extensor carpi ulnaris* to *extensor carpi radialis brevis*)

- In terms of FCU is too spastic.
- FCU is being used to be transferred across to fingers to correct the deformity.
- In case when FCR is not strong enough to be transferred and wrist is in ulnar deviation. In this case ECU to ECRB. However, FCU lengthening should be considered to correct ulnar deviation (2).
- In terms of biomechanically ECU is more identical to ECRB. ECU is subluxed on the palmer aspect due to loss of tendon

sheath. As a result of this it becomes a flexor and ulnar deviation (6).

Option 3: BR – ECU: (*brachioradialis* to *extensor carpi ulnaris*)

- In terms of using *brachioradialis* (BR) and *extensor carpi ulnaris* (ECU) as a transfer option it will not disrupt the balance between flexors and extensor thus preventing overcorrection. However, the draw back will be it might need correction/ lengthening of FCU.

Hand deformity assessment

Wrist should be kept in neutral, and assessment of finger posture should be made. In case of wrist in neutral and there is failure of extension of thumb and finger then next step would be lengthening of tendons. However, this is indicated when the deformity corrects itself when wrist is in flexion. If there is persistence of tightness with wrist in flexion, then tendon transfer will the next option for deformity correction (2).

Option 1: FDS – FDP transfer: (*flexor digitorum superficialis* to *flexor digitorum profundus*)

AS mentioned above tight flexors that are not able to correct itself with wrist in full extension will need tendon transfer option. FDS is sutured as distally as possible and then cut distally. FDP are sutured proximally and then transacted proximally. Proximal FDS is stitched to distal FDP (2). FDS and FDP are biarticular as they work on the wrist as well as the finger. Addressing the finger deformity should be considered along with correction of wrist. Flexor pronator slide can be one option. STP (*superficialis* to *profundus*) transfer has been reported for severely disabled hands by some authors (8).

Option 2: FCU – EDC: (*Flexor Carpi Ulnaris to Extensor Digitorum Commins*)

In cases when there is no active extension of metacarpophalangeal joint (2). However, there is some debate in the literature in terms of whether this transfer is deemed necessary or not. Some authors have published results following this transfer. However, others are off the view that the concept of balancing the wrist is more important rather than focussing on this transfer (8).

Static deformity correction

Wrist arthrodesis

It is indicated for patients with cerebral palsy having static deformity for cerebral palsy in children in case of boys 12 years and girls 14 years of age. In some cases, patients can be graded as Zancolli grade III. The contraindications of wrist arthrodesis is in patients with adequate grip strength as wrist arthrodesis will take away the tenodesis affect and thus lead to deterioration of function (3, 10). (Fig. 5).

It involves three broad steps.

- Soft tissue releases both from flexor and extensor side.
- Bony corrections in terms of proximal row carpectomy, wedge resection of midcarpal to correct the deformity and bring the wrist to neutral position. Articular cartilage needs to be removed using bone burr to help in fusion.
- This followed by stabilization of desired position using AO wrist plate.
- Immobilization in a cast till there is evidence of fusion (2).

Swan Neck deformity

It is indicated for Swan Neck deformity provided there is active movement of fingers and greater than 20 degrees of extension deformity at the PIPJ. Some authors have suggested greater than 40 degrees of deformity should be considered for intervention (2, 8).

The options available for correction are:

1. Lateral band rerouting.
2. Lateral band tenodesis.
3. Spiral ligament reconstruction.
4. Intrinsic muscle slide
5. Resection of ulnar nerve at the Guyon s' canal (2, 8).

Thumb deformity correction

In terms of addressing the deformity three steps can be considered:

I. Release of contracture.
II. Augmentation of weak muscle.
III. Joint stabilization (4, 9).

In terms of deformity of thumb intrinsics are most likely to be involved so release of adductor pollicis along with first dorsal interossei should be part of any reconstructive procedure. FPB (*flexor pollics brevis*) on contrary is less likely to be involved. EPL (*extensor pollicis longus*) tendon work more efficiently as adductor and hyper extensor at IPJ (interphalangeal joint) when thumb is adducted (2). Part of it can be explained likely that this position of thumb is likely to provide the tendon with straight line of pull.

Rerouting of EPL tendon is the tendon transfer of choice. (Fig. 6). However, the tendon function needs to be assessed with wrist in neutral position. EPL transfer can lead to passive hyperextension of IPJ so capsulodesis can be considered to address this issue. In case EPL tendon is not strong enough to provide extension at IPJ then next option can be transfer of brachioradialis to EPB (*extensor pollics brevis* tendon) (2). House published classification of in-palm deformity of thumb and discussed type of intervention based on the degrees of deformity which is mentioned below:

- **Type I:** metacarpophalangeal joint (MCPJ) adduction contracture intrinsic muscle deformity (most common). Release of intrinsic muscle is the first step is done for type I deformity.

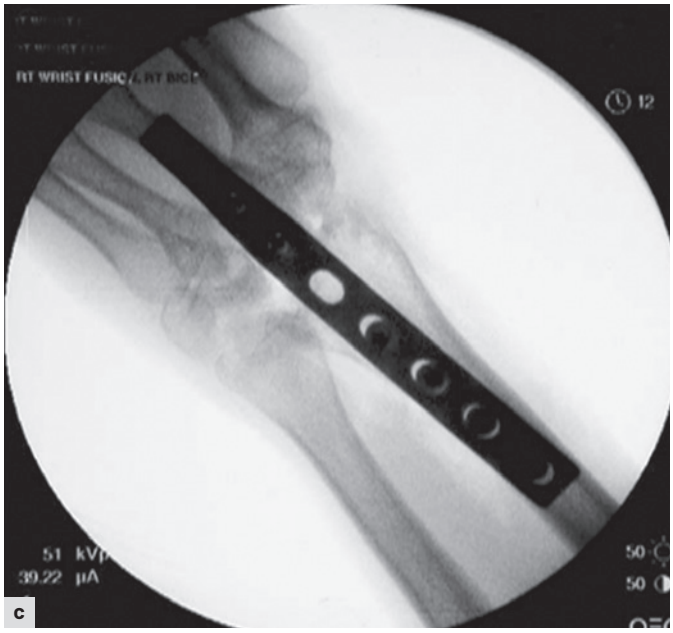

Fig. 5. **Wrist fusion.**

Reference: Van Heest AE. Surgical management of wrist and finger deformity. Hand Clin. 2003;19:657–665. doi: 10.1016/s0749-0712(03)00076-3.

- **Type II:** Type I with MCPJ flexion contracture (extrinsic muscle deformity).
  It should start with release of intrinsic muscles, and this should be followed by release of extrinsic which involve using a tendon slide to release the FPL tendon spasticity. This might be sufficient for type II deformity, or it may need further releases.
- **Type III:** Type I with MCPJ hyperextension deformity or instability (combined). Adductor release followed by FPL (*flexor pollicis longus*) tendon slide, EPL (*extensor pollicis longus*) transfer to EPB (Extensor Pollicis Brevis) tendon along with brachioradialis to APL (*abductor pollics longus*) transfer. Stabilization of joint can be addressed by capsularraphy, sesamoid arthrodesis or fusion. APL tendon function can be restored by transfer of PL, BR or FDS. Manske procedure involves release of EPL tendon proximal to Lister s' tubercle and then passed through the first dorsal compartment and rejoined to attach the thumb in abduction and extension.
- **Type IV:** Type I with MCPJ and Interphalangeal joint flexion contracture. (Combined deformity most common).

For type 4 again the above steps of correction should be followed along with correction of IPJ deformity. If IPJ is not extendable then plication of EPB can be used as an option. EPB can be tenodesed to FCR tendon (4).

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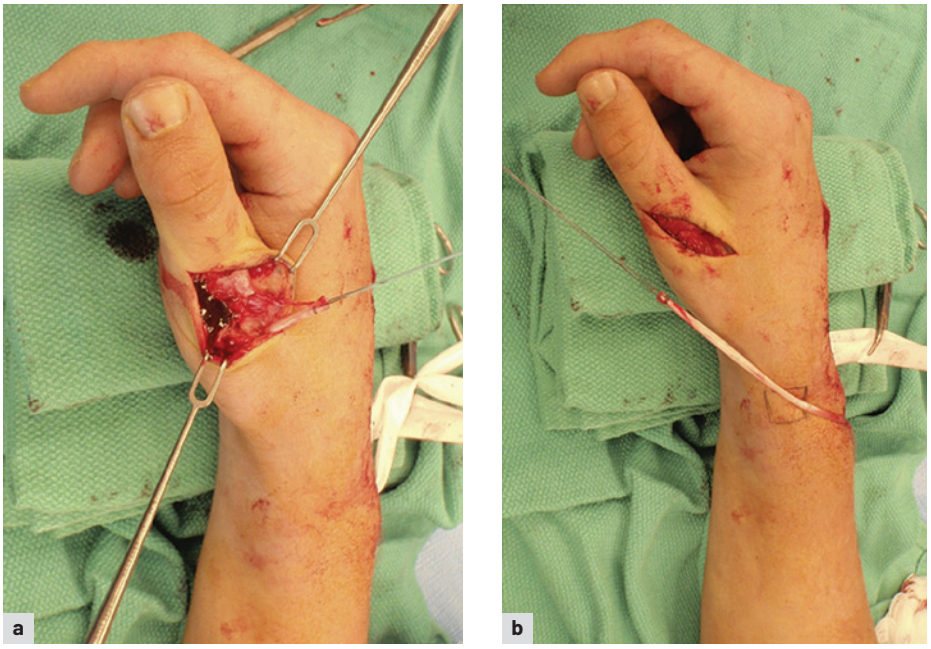

Fig. 6. **Harvesting of EPL tendon and transfer to the proximal end of wound to allow thumb abduction.**

Reference: Van Heest AE. Surgical technique for thumb-in-palm deformity in cerebral palsy. J Hand Surg Am. 2011;36: 1526–1531. doi: 10.1016/j.jhsa.2011.06.014.

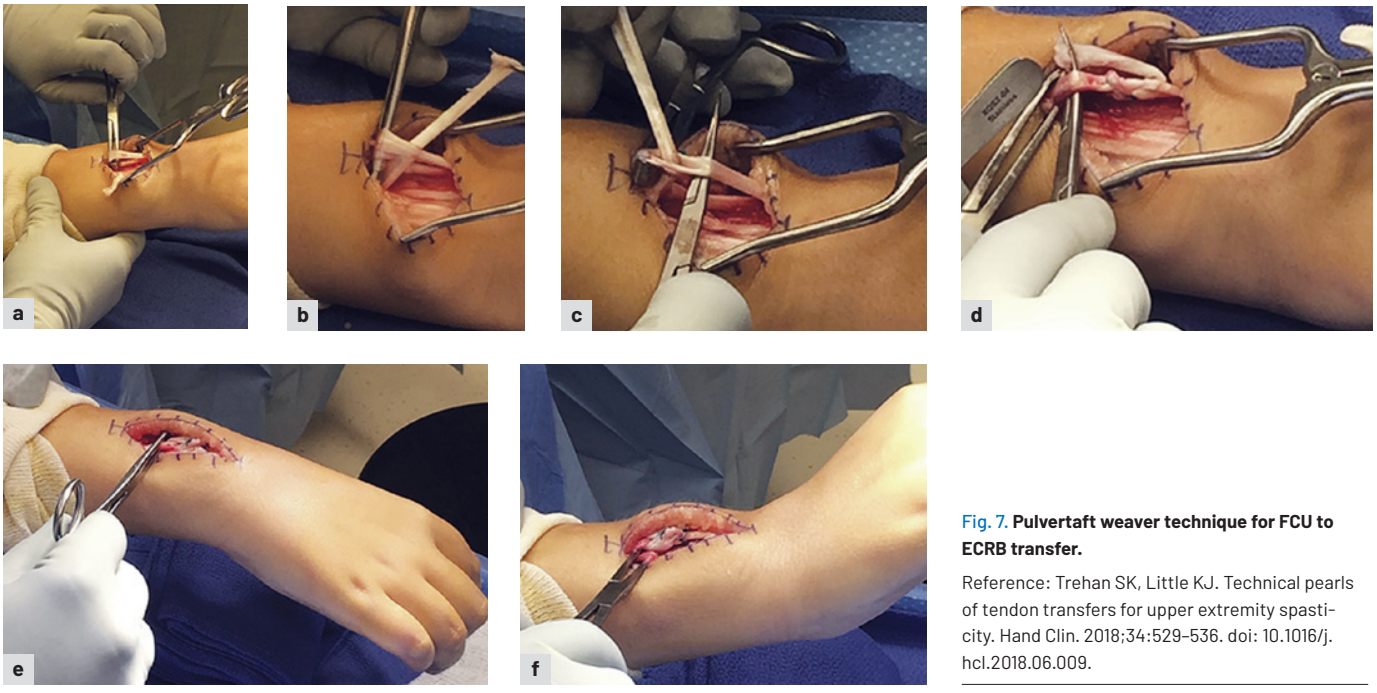

Fig. 7. **Pulvertaft weaver technique for FCU to ECRB transfer.**

Reference: Trehan SK, Little KJ. Technical pearls of tendon transfers for upper extremity spasticity. Hand Clin. 2018;34:529–536. doi: 10.1016/j.hcl.2018.06.009.

DISCUSSION

In terms of use of inclusion and exclusion criteria the idea of this systemic review was to provide young paediatric surgeons and trainees a framework where they can look at and proceed with management with a clear understanding in mind about what to do and when to do as part of surgical team for these patients. We fully appreciate that a lot of these decisions are part of MDT (multidisciplinary team) discussions based on outlook of different health professionals. However, we wanted to update and support our surgeons and trainees interested in hand deformities secondary to cerebral palsy with this piece of work that can be a useful contribution to the literature from operative intervention point of view. Critically evaluating the exclusion criteria one can see that the highest number of studies that were excluded were retrospective reviews where patients were followed following surgical

intervention which has got its own utility. However, we focussed on rationale of offering surgical intervention with aim of provision of better quality of life.

Tendon transfer principles should be kept in mind that I have been discussed above. Following transfer there are different techniques mentioned in the literature that can be used to secure the transfer. The Pulvertaft weaver (Fig. 7) involves orthogonal slit in recipient tendon. Surgeons have discretion in terms of type of sutures, interlacing weavers, type of suture and type of stich used. The downside of this procedure is increased bulk of construct and increased use of tendon length. Other options available are side to side, end weaver, lasso, loop tendon, wrap around, double loop and spiral technique. Different surgeons have reflected on their techniques compared to Pulvertaft techniques in terms of strength and reliability of stabilization of transfer (6).

However, despite of all the work up and assessment it is worth noting that all patients are different. In terms of paediatric population, we are meeting the needs of our patients along with their care givers and parents. In this regard they become an important pillar of any management plan. They can require lifelong follow up and intervention in some cases as the child grows their functional demand changes, and they might require further procedures to cope with the needs of growing bodies. However, managing expectations is of paramount importance here. What we are trying to achieve here is to deal with spastic deformities of upper limb in principal and making sure that hand and wrist can be brought as close to normal as possible, but it is worth highlighting here that upper extremity affected by cerebral palsy will not be normal but as surgeons we can try to improve the functional outcome, but it cannot be compared with their good hand or wrist.

Moreover, the functional requirements and circumstance cannot be generalized for every patient. An individual based approach, centred around needs, expectations and experience of surgeon should be considered for acceptable possible outcome.

The type of intervention and age of intervention has been under debate as well but based on our understanding of literature the prime drive of intervention is the child itself. This hold particularly true for patients with deformities of thumb where the age of intervention is between 7 and 10 years as this is considered the age where child is sensible enough to grasp things and understand the limitation that the thumb is causing it in terms of activities of daily living. Surgical intervention should be avoided in cases where there is lack of voluntary movement of hand or there is manifestation of dystonia or extrapyramidal disease (9).

In terms of Swan Neck deformity, it is addressed with active PIP extension of >20 degrees. One study suggest that intervention should be addressed if PIP >40 degrees. However, it is worth mentioning here that there are some contraindications for this procedure. In case there is fixed MCPJ block. In these cases, fusion is a likely option. Intrinsic release should not be performed in patients with weak extrinsic flexors as they will be the muscles help in finger flexion at MCPJ. Active flexion of PIPJ is mandatory for this procedure as the risks of recurrence is high in cases of lack of active flexion at these joints (1).

CONCLUSIONS

In conclusion cerebral palsy management is a complex issue especially when it comes to management of wrist and hand issues but team working, understanding limitations and good communication can lead to optimum results. ■

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