Original Article

Neurovascular Complications in Hinged External Fixator of the Elbow

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Background: The use of a hinged external fixator on elbow is an effective procedure. Several international publications reported the results of the treatment after using the fixator. However. there was no reported study focusing on the neurovascular complications.

Objective: To report the result of hinged external fixator surgery in patients with instable elbow conditions focusing on the neurovascular complications.

Materials and Methods: A retrospective review of patients with applied hinged external fixator of the elbow between April 2011 and May 2017 at HRH Princess Maha Chakri Sirindhorn Medical Center, Srinakharinwirot University in Nakhon Nayok Province was performed. The data of complications were collected from the surgery until 16 weeks after the procedure.

Results: Thirteen patients of traumatic elbow had hinged external fixator applied. The authors found that neurovascular complications occurred in four cases (30.8%). One case developed a major neurovascular complication, which was permanent radial nerve damage (7.7%). The other three cases developed minor neurovascular complications, which was transient radial nerve injuries in two patients and transient ulnar nerve injury in one patient (23.1%). One case developed ulnar fracture associated with hinged external fixator (7.7%).

Conclusion: Hinged external fixator of the elbow is considered an effective device. However, high complication rates have been detected. Therefore, orthopedic surgeons should be aware of the complications, especially the radial and ulnar nerve injury.

Keywords: Hinged external fixator, Elbow, Complications, Radial nerve injury

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The hinged external fixator (HEF) has been used over the past 10 years to treat elbow disorders. It has been widely accepted as a newer operative device and used worldwide. The HEF is usually used in patients suffering traumatic complex fracture-dislocations of the elbow and in patient with elbow joint instability from other conditions such as ligamentous injuries, septic arthritis, or fracture of the distal humerus[1-4]. The benefits of HEF is to provide sufficient stability to allow early post-operative mobilization of the elbow[5,6]. Nevertheless, the complications in the use of HEF are still of concern as it needs to be placed close to the major neurovascular structures[7]. The complications of HEF of the elbow are higher compared to applying an external fixator in other sites[8]. Mostly, the concerns are neurovascular complications such as nerve damage, both temporarily and permanently, compartment syndrome, and vascular injury[9-11].

The objective of the present study was to describe the results of treatment of patients with injuries of the elbow treated with a HEF, and to investigate the complications of HEF especially the neurovascular complications.

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Materials and Methods

The present study received permission from

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the Ethics Committee of the Faculty of Medicine, Srinakharinwirot University. The authors collected data from all the patients who had a HEF applied to the elbow by orthopedic surgeons (specialist upper limb) at HRH Princess Maha Chary Sirindhorn Medical Center, Srinakharinwirot University in Nakhon Nayok Province between April 2011 and May 2017.

The complications of HEF of the elbow that were investigated could be classified into major neuro-vascular complications, which include permanent nerve damage, compartment syndrome, and vascular damage, and minor neurovascular complications, which include temporary nerve damage and temporary vascular occlusion. Other complications such as elbow joint infection, fracture associated with HEF, severe pin-track infection, and reflex sympathetic dystrophy were also noted.

Nerve injuries were defined as numbness area along the nerve distribution on the skin by patient and confirmed with pinprick or fine touch methods. The motor weakness was tested along the innervation of the motor branch of the radial nerve, median nerve, and ulnar nerve.

The data collection was done from immediately after the surgery and repeated until 16 weeks post-operative follow-up. The patients were followed for their clinical conditions weekly after the operation. All patients had appointments at least 16 weeks after the surgery depending on the problem, diagnosis, and conditions. The final report of the complications of HEF of the elbow was done at the sixteenth week following the surgery.

Surgical technique

The surgeons performed the operation under general anesthesia and a pneumatic tourniquet was applied at the arm as proximal as possible. All patients received antibiotic prophylaxis. The patients were placed in supine position and the affected arm was laid on the surgical table and the elbow and forearm were allowed to move freely. The choice of approach depended on type of fractures or dislocations, previous skin incisions, open wounds, and nerve injuries. In the first step, the surgeon treated the associated fractures with osteosynthesis and repaired the injured ligament using bone anchors or trans-osseous sutures.

When applying the HEF, the surgeon would insert a Steinmann pin through the center of rotation of the elbow under the anterior cruciate ligament (ACL) tibial guide, assisted by fluoroscopy. Next, the fixator was positioned over this pin with its proximal and distal arms aligned over the humerus and ulna. Then, through a small incision, the surgeon blunt dissected to the bone and the soft tissue protective sleeve was placed directly over the bone while pre-drilling and inserting the Schanz pins. Then, the surgeon secured the frame to the humeral and ulnar bone with two Schanz pins in each bone. To apply the humeral pins, the surgeon did the operative technique described by Kaminani that the absolute safe zone for pin entry into the lateral distal humerus is lying within 100% of a line, equivalent in length to the patient's own trans-epicondylar distance (TED), when projected proximally from the lateral epicondyle[12]. The fixator was aligned and adjusted and then the Steinmann pin was removed. The range of motion of the elbow was checked. Finally, the fluoroscopy was used to confirm the concentric reduction of the elbow or associated fracture and position of the Schanz pins. A passive worm gear incorporated into a HEF was used to mobilize the elbow initially, and active mobilization was gradually introduced. The patient was allowed to move the elbow freely until the limit of flexion or extension was reached. The HEF was removed at an average of eight weeks after the procedure.

The hinge external fixator

The HEF used in the present study was a uni-planar HEF (Orthopeasia Co., Ltd., Thailand) made of metal and radiolucent plastic that was designed to be applied in lateral side of elbow. The hinge mechanism comprises of an adjustable hinge joint that can be set to a range of motion on flexion and extension degree. A distraction mechanism allows for concentric distraction of the joint of up to 10 mm. The hinge joint of the external fixator has a central hole that is designed to be concentric with the center of rotation of the elbow; therefore, the Steinmann pin can be passed through the hole to align with the hinge.

Statistical data analysis

The authors reported as frequency and percentage in all categorical variables. Mean with standard deviation and median with range were used to describe for continuous variables. All statistical analyses were performed using IMB SPSS Statistics software, version 23.0 (IBM Corp., Armonk, NY, USA).

Results

The HEF was performed in 13 patients. The mean ages of patients were 42.38±20.04 years (Range 17 to 80 years). Six patients were female and seven were male. Five fixators were applied in the right elbow and eight fixators were applied in left elbow

(Table 1). All patients completed their follow-up. The lateral approach was performed in nine patients, the posterior approach was performed in two patients, and two patients had the HEF applied without incision. In seven patients, the surgeon identified and protected the ulnar nerve. A subcutaneous anterior ulnar nerve transposition was also performed in two of seven patients at the end of the procedure. No clinical evidence of neuropathy was detected before surgery in any of the patients.

Table 1. Demographic data of patients

Variables	n (%)
Sex (n=13)	
Female	6 (46)
Male	7 (54)
Age (years)	
Mean±SD	42.38±20.04
Median (range)	49.00 (17 to 80)
Total elbow (n=13)	
Right elbow	5 (38)
Left elbow	8 (72)

SD=standard deviation

The HEF was in place for a mean time of 3.6 weeks (1 day to 16 weeks). The time of HEF removal depended on the stability of the elbow, the range of motion, and the conditions of the pin sites. The mean removal time was 7.6 weeks (range 6 to 12 weeks). Twelve patients had traumatic dislocation of the ulnohumeral joint. Seven of those 12 patients had associated fractures including the head of the radius, the coronoid process, the distal humerus,

Table 2. Details and results in 11 patients with complex instability of the elbow

Case	Age (year)	Sex	Mechanism of injury	Associated fractures	Open/ closed injury	Neurovascular status	Time to HEF	Associated procedures	Distance between PP to LE (mm)	Time in HEF	Complications	Final ROM (degree)
1	80	F	Fall	-	Closed	Normal	7 weeks	LCL repaired UI	58	8 weeks	-	90
2	51	M	MVA	Distal humerus	Open	Normal	2 weeks	I+D, ORIF LCL repaired UT	60	9 weeks	Radial nerve palsy	90
3	58	M	Infection	-	-	Normal	1 day	I+D	68	12 weeks	-	85
4	29	M	Fall	Coronoid RH	Closed	Normal	5 days	ORIF LCL repaired	32	6 weeks	Radial nerve palsy	95
5	31	M	Fall	RH Distal radius	Open	Normal	1 week	I+D, ORIF LCL repaired RH resection	54	7 weeks	Ulnar nerve palsy	120
6	49	M	MVA	-	Closed	Normal	1 week	LCL repaired UI	65	8 weeks	-	125
7	17	F	Fall	-	Closed	Normal	4 weeks	OR LCL repaired UT	55	7 weeks	Ulna fracture	85
8	50	F	Fall	-	Closed	Normal	3 weeks	CR LCL repaired	59	6 weeks	Radial nerve palsy	125
9	49	F	MVA	Radius Ulna	Closed	Normal	3 weeks	ORIF CR, UI	34	6 weeks	-	115
10	19	M	Fall	Coronoid RH	Open	Normal	1 week	I+D	55	7 weeks	-	110
11	24	M	Fall	Coronoid RH	Closed	Normal	3 weeks	LCL repaired ORIF, arthroscopy	51	6 weeks	-	130
12	70	F	Fall	Coronoid RH	Closed	Normal	4 weeks	LCL repaired	41	9 weeks	-	125
13	24	F	MVA	-	Closed	Normal	16 weeks	-	51	8 weeks	-	60

HEF=hinged external fixator; MVA=motor vehicle accident; LCL=lateral collateral ligament; UI=ulnar nerve identified; ORIF=open reduction and internal fixation; UT=ulnar nerve transposition; RH=radial head; CR=closed reduction; OR=open reduction; I+D=irrigation and debridement; PP=proximal pin; LE=lateral epicondyle; F=female; M=male

Figure 1. Case 8. A) A fifty-year-old female fell on the right, dominant arm and sustained a simple posterior elbow dislocation. After closed reduction, the elbow remained unstable without any neurological deficit. Because the patient had persistent instability, open repair of lateral ulnar collateral ligament and application of HEF were performed. B) Postoperative anteroposterior and lateral radiographs. The elbow joint was reduced with HEF. The proximal pin was 59 mm from lateral epicondyle. Postoperatively, complete radial nerve palsy was observed.

and the shaft of the radius and ulna. One patient had sustained elbow instability from chronic tuberculous infection. The mean distance between the proximal pin and the lateral epicondyle was 53 mm (range 32 to 68 mm). None of the proximal pins was placed further proximally to the patient's own TED, when projected proximally from the lateral epicondyle. At final follow-up, the mean range of motion was 104.2° (range 60° to 130°) and all patients had concentric reduction of the elbow (Table 2).

In the 13 surgeries, four patients (30.8%) developed neurovascular complications, one patient (7.7%) was classified as major neurovascular complication, and three patients (23.1%) were classified as minor neurovascular complication, but only one of the four patients required reoperation. The complications were radial nerve palsy in three patients (23.1%) that experienced weakness of fingers extension or numbness in first web space following surgery, and an ulnar nerve palsy was found in one patient (7.7%) that experienced numbness in half of ring and little finger. In three patients, the nerve injury recovered spontaneously after 10 weeks of conservative treatment. However, one patient (case 8) (Figure 1) whose radial nerve palsy did not recover by conservative treatment 12 weeks after

Table 3. The efficacies and complications in hinged external fixator of the elbow

Article	Efficacies	Complications
Cheung, et al.[7] (n=100)	Did not report	Overall complications=25% - Minor complications*=15% - Major complications**=10%
McKee, et al.[6] (n=16) • Recurrent complex elbow instability	• Mean range of flexion-extension=105 degrees (65 to 140) • Mean Morrey score=84 (49 to 96)	Overall complications=38% - Fractured humeral pin=1 - Temporal radial nerve palsy =1 - Recurrent instability =1 - Wound infection=1 - Severe pin-track infection=1 - Reflex sympathetic dystrophy= 1
Baumann, et al.[9] (n=3) • Chronic elbow instability (1) • Elbow dislocation (1) • Fracture-dislocation of the elbow (1)	Did not report	Complete radial nerve palsy=3 - Refused surgical treatment=1 - Tendon transfer for radial nerve palsy=1 - Nerve reconstruction and tendon transfer=1
Stavlas, et al.[10] (n=8) • Supracondylar fracture (3) • Fracture-dislocation of the elbow (5)	• All the fractures were united • All the patients maintained a functional range of motion of the elbow	Overall complications=38% - Radial nerve palsy=1 - Pin-track infection=2

* Minor complications included local erythema and non-purulent drainage lasting greater than 5 days and the need for skin release

** Major complications included purulent pin site drainage, fixator malalignment, pin loosening, and deep infection

the operation. Therefore, she was performed radial nerve exploration after removal of the HEF. A nearly complete disruption of the radial nerve was detected and its relationship to the distal humeral pinhole and later interfascicular nerve grafting using the sural nerve with tendon transfer with pronator teres to extensor carpi radialis brevis was operated. Four months after surgery, this patient had stable elbow motion with 130° of flexion, a 5° loss of extension and recovered from radial nerve palsy with 40° of active wrist extension and active thumb and finger extension. One patient (7.7%) developed a fracture of the ulna shaft through the ulnar Schanz pin insertion site two weeks after surgery because she had disuse the osteopenia from the congenital hydrocephalus; therefore, there were several contributory factors for this complication including lack of compliance of the patient and early loosening of the ulnar pins in disuse osteopenia bone, which allowed excessive movement of the pins and lead to increase stress on the ulna. The ulna fracture was treated by open reduction and internal fixation with LCP plate and revision of the ulnar Schanz pin of HEF.

Discussion

There have been a few studies that reported the incidences and types of complication of applying HEF of the elbow. Cheung et al reported 100 patients who were treated with HEF. Fifteen percent of his patients developed minor complications including local erythema, non-purulent drainage, and the need for skin release to decrease tension adjacent to the pins. Additionally, 10% developed major complications including purulent pin site drainage, fixator mal-alignment, pin loosening, and deep infection. They did not find nerve injuries associated with pin placement. The reason may be explained because the humeral pins were typically placed percutaneously by incision of the skin but the surgeons performed a blunt dissection to the bone and placed of a drill sleeve while pre-drilling to insert the pins and, in many instances, the humeral pins were placed under direct visualization[7]. McKee et al reported 16 patients with recurrent complex elbow instability using a HEF. Six of his patients (38%) developed complications including one fractured humeral pin, one recurrent instability, one wound infection, one severe pin-track infection, one patient with reflex sympathetic dystrophy, and one for temporary palsy of the radial nerve, which recovered after ten weeks of conservative treatment[6]. Baumann et al reported three cases of radial nerve palsy due to complete nerve disruption after application of a HEF by using percutaneous placement of the humeral pins for the treatment of complex elbow injuries and all three patients had been operated on by experienced elbow surgeons. Therefore, these authors recommend placing these pins through an open approach[9]. Clement et al reported percutaneous insertion of external-fixator half pins in the lateral side of the distal humerus that was performed in 20 upper limbs

of 20 cadavers 3 cm (the distal pin) and 5 cm (the proximal pin) proximal to the elbow joint line through a 1 cm skin incision. The author showed radial nerve injury in four of the 40 placed half pins. In all these cases, the half pin passed directly through the nerve. The proximal half pin impaled the nerve in one case and the distal half pin in three cases. The radial nerve was directly in contact with the pins in nine cases. Therefore, these authors concluded that humeral pins should be placed in an open manner only[8] (Table 3).

The radial nerve injuries can occur following stabilization of complex elbow dislocation by using a HEF, because radial nerve obliquely across the distal part of humerus from posterior compartment to anterior compartment by piercing the lateral intermuscular septum to reach the lateral side of humerus, so the course of the radial nerve in distal part of humerus closely relate to the humeral pins of HEF[8,13,14]. Gausepohl et al reported that area of pin implantation in the distal part of the humerus as near as 6 cm proximal to the lateral epicondyle was safe[13]. Kamineni et al found that the radial nerve crossed the humerus from posterior compartment to anterior compartment at an average of 102±10 mm from the lateral epicondyle. The author defined the absolute safe zone for pin entry into the lateral distal humerus as the area lying within the caudad 100% of a line, equivalent in length to the patient's own TED, when projected proximally from the lateral epicondyle. The author's observations regarding pin trajectory were that a proximal lateral to medial trajectory was consistent, since the humeral cortex at this level was relatively smooth and more circular and more in keeping with a tubular long bone. However, a more distal pin could not be placed consistently without posing a neurological risk, since the lateral supracondylar ridge at this level was sharp and narrow, as a consequence of skidding forward on the initial attempt insertion and damage the radial nerve or wrap soft tissues around the drill bit or pin thereby causing a radial nerve traction injury[12].

In the present study, one case (7.7%) developed a major neurovascular complication that was permanent radial nerve damage from a nerve grafting with tendon transfer. Three cases (23.1%) developed minor neurovascular complications with two transient radial nerve injuries and one transient ulnar nerve injury that recovered spontaneously after conservative treatment. One case (7.7%) developed an ulnar fracture associated with HEF in disused osteopenia patient.

Most complications in the present study were associated with nerve injuries. There were complications of radial nerve because the humeral pins of HEF were inserted in the lateral distal third of the humerus so the radial nerve was at risk for injury during an operative procedure in this area and although the insertion of Schanz pins were placed in the absolute safe zone for pin entry into the lateral distal humerus following a small skin incision and the pins were inserted with use of the appropriate protective sleeves by experienced surgeons. Nevertheless, there was radial nerve palsy in three patients suggesting that this complication was underestimated. The cause of iatrogenic radial nerve injury might be that the trajectory insertion of distal pin to the narrow lateral supracondylar ridge was potential for the drill bit or pin to either skid anteriorly and damage radial nerve or the radial nerve traction generated as surrounding soft tissues were wrapped around the pin. The complication of ulnar nerve may have occurred when the percutaneous applying of ACL tibial guide to medial epicondyle of humerus to identify the center of rotation of the elbow, which may lead to ulnar nerve irritations.

The relatively high rate of radial nerve injury leads us to strongly recommend an open approach with extension of the skin incision to allow blunt dissection to the lateral cortex of the humerus before predrilling and insertion of humeral pins under the use of soft tissue protective sleeves and direct visualization. To prevention of ulnar nerve injury, during the step in identifying the center of rotation of elbow, a mini skin incision over medial side of elbow should be applied to identify medial epicondyle to protect and possibly to retract the ulnar nerve while the ACL tibial guide is applied.

Conclusion

The HEF of the elbow is considered an effective device to provide stability and to allow early motion of the elbow. However, the high complication rates detected in the present study should remind the practitioner that when applying of HEF one should be aware of complications particularly radial and ulnar nerve injury.

What is already known on this topic?

The HEF has been widely accepted as a newer operative device for traumatic complex fracture-dislocations of the elbow or elbow joint instability from other conditions. The benefit of HEF is to provide sufficient stability to allow early post-operative mobilization of the elbow. Nevertheless, the complications of HEF are still of concern as it needs

to be placed close to major neurovascular structures of the elbow.

What this study adds?

The HEF of the elbow is effective to provide stability and to allow early motion of the elbow. Nevertheless, the high rates of nerve injuries detected in the present study remind the practitioners to be aware of its complications particularly, the radial and ulnar nerve injury.

Conflicts of interest

The authors declare no conflict of interest.

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