CLINICAL ARTICLE

Open Arthrolysis for Chronic Elbow Dislocation with Extremely Severe Stiffness in Children

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Objective: Studies on extremely severe elbow stiffness after chronic dislocation in children are scarce. This study aims to investigate the choice of surgical treatment modalities and to analyze their treatment efficacy in children with chronic elbow dislocation with extremely severe periarticular stiffness.

Methods: Data of 21 children with chronic elbow dislocation with extremely severe periarticular stiffness diagnosed and treated in our department between February 2015 and February 2021 were retrospectively analyzed. Twenty boys and one girl were included in the study, their mean age was 11 ± 2.5 years, and they had concomitant distal humerus fractures. For the treatment protocol, all children with extremely severe elbow stiffness were treated with open arthrolysis, and elbow joint stability was intraoperatively assessed. All children performed passive functional exercises the day after surgery. The elbow flexion and extension angles, range of motion (ROM), and Mayo score were evaluated preoperatively and at the final follow-up.

Results: Of the 21 children, only one had recurrent severe stiffness of the elbow joint after surgery; nevertheless, the function was still improved compared with that before surgery. Preoperatively, the mean elbow extension and flexion angles were 72.2° ± 12.7° and 93.6° ± 11.1°, respectively, and the range of motion (ROM) of the elbow joint was 17.8° ± 8.3°. At the final follow-up, the mean elbow extension and flexion angles were 22.7° ± 18.6° and 118.8° ± 15.4°, respectively, and the elbow joint ROM was 96.1° ± 17.4°. The differences in the preoperative and postoperative ROMs, flexion angles, and extension angles of the elbow joint were significant ($p < 0.01$). The MEPS at the final follow-up was 78.57 ± 14.24, which was significantly higher than preoperative (29.76 ± 10.89), and the excellent rate was 81%.

Conclusion: Open arthrolysis and open reduction and internal fixation of the elbow joint are effective in treating chronic elbow dislocation with extremely severe stiffness in children.

Key words: Dislocation; Elbow; Stiffness; Treatment; Children

Introduction

Elbow dislocation is uncommon in children, with an overall incidence of 3%. If not treated properly and promptly, elbow dislocation will inevitably result in severe loss of elbow function and eventual pain.[1] Post-traumatic elbow stiffness is defined as a range of motion (ROM) for active flexion and active extension of <120° and >30°, respectively. It may be accompanied by rotational dysfunction and has an incidence of 3%–20%.[2] Based on the elbow flexion-extension ROM, Mansat and Morrey[3] classified post-traumatic elbow stiffness into mild (flexion–extension ROM of <90°), moderate (flexion–extension ROM of 60°–90°), severe (flexion–extension ROM of 30°–60°), or extremely severe (flexion–extension ROM of <30°) elbow stiffness.

Currently, many studies have reported on the diagnosis and treatment of elbow stiffness in adults, although there is limited literature on its treatment in children. Moreover, studies on extremely severe elbow stiffness after chronic dislocation in children are scarce and cases have not yet been reported. Chronic elbow dislocation in children with extremely severe stiffness not only seriously affects the function of the affected limbs, but also has a profound effect on

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TABLE 1 Comparisons of elbow flexion, extension, rotation, and MEPS ($\bar{x}\pm s$)

	Flexion–extension ROM	Extension angle	Flexion angle	Forward rotation angle	Backward rotation angle	Rotational ROM	MEPS	Proportion of good or excellent scores (%)
Preoperative	17.8 ± 8.3 (5–28)	72.2 ± 12.7 (55–90)	93.6 ± 11.1 (70–105)	68.3 ± 12.9 (50–80)	76.4 ± 12.1 (55–85)	144.7 ± 19.3 (110–160)	29.76 ± 10.89 (10–45)	81
Final follow-up	96.1 ± 17.4 (20–130)	22.7 ± 18.6 (0–65)	118.8 ± 15.4 (80–135)	69.8 ± 15.3 (55–85)	78.1 ± 17.4 (50–90)	147.9 ± 20.1 (115–175)	78.57 ± 14.24 (35–100)	
T	−21.0	11.6	−9.8	−1.2	−0.5	−1.4	−17.43	
p-value	<0.01	<0.01	<0.01	>0.05	>0.05	>0.05	<0.01	

Abbreviations: MEPS, Mayo Elbow Performance Score; ROM, range of motion.

the children's daily living activities, growth and development, and psychological well-being. So, we put forward the hypothesis that the same treatment experience for adults applies to children, but children have their own unique characteristics. The aim of the study is to (i) report the therapeutic effect of open arthrolysis in the treatment of chronic elbow dislocation with severe stiffness in children; (ii) analyze the mechanism of injury and the principle of treatment; (iii) summarize the suitable treatment strategy.

Materials and Methods

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (i) children (<14 years old) hospitalized for elbow dislocation; (ii) elbow ROM <30°, medical history >3 months; (iii) the primary surgical method was open arthrolysis.

The exclusion criteria were as follows: (i) non-traumatic elbow dislocation in children, such as tumor, infection, etc.; (ii) children with other diseases, such as osteogenesis imperfecta, cerebral palsy, intellectual disability, etc.; (iii) children have received elbow joint surgery before admission.

General Characteristics

A total of 21 children, 20 boys and one girl, were included in the study, with a mean age of 11 ± 2.5 (range, 5.8–14) years. The injured limbs had no previous surgical treatment history. The preoperative range of motion of the elbow joint in this study is shown in Table 1.

This study was approved by the Institutional Review Board (IRB) of Sichuan Province Orthopedic Hospital [IRB no. KY2020-006-01]. All patients provided written informed consents.

Surgical Procedure

Anesthesia and Positioning

Under general anesthesia and brachial plexus block anesthesia, the patients were placed in the supine position, with a tourniquet tied to the upper arm of the affected limbs.

Open Arthrolysis

Combined Medial and Lateral Approach. In 16 of the 21 children, lateral elbow approach (modified Kocher approach) combined with medial elbow approach (Hotchkiss approach) was used. First, the skin, subcutaneous tissue, and deep fascia were incised *via* the lateral approach to reveal the outer edge of the distal humerus. The anterior and posterior portions of the distal humerus were exposed *via* subperiosteal separation, and extracapsular hyperplastic scarring, osteophytes, and heterotopic ossification were resected. The humeroradial joint capsule was opened, and the intra-articular adhesions and osteophytes were removed until the humeroradial joint surface was fully exposed. Subsequently, the skin, subcutaneous tissue, and deep fascia were incised *via* the medial approach to expose and to protect the ulnar nerve, and the distal humerus was entered at the medial margin *via* the subperiosteal approach to expose the humeroulnar joint. The intra-articular adhesions and osteophytes were removed until the humeroulnar joint surface was fully exposed. After completion of the release, the elbow joint could be reduced without resistance.

Medial or Lateral Approach Alone. The medial approach to the elbow joint was used in one patient and the lateral approach in two. The medial and lateral procedures were the same as described above. After completion of the release, the elbow joint could be reduced without resistance. The specific procedures for the medial and lateral releases were as described above.

Anterior Approach. The anterior approach was used in one patient, *via* an S-shaped incision across the skin folds of the anterior elbow, freeing to protect the neurovascular structures and exposing the space between the flexor insertion and biceps tendon. The musculus brachialis was opened, and the heterotopic ossification on the anterior side of the elbow joint was removed. The anterior joint capsule of the elbow was incised to expose the humeroulnar joint, and the intra-articular adhesions and osteophytes therein were removed until the elbow joint could be reduced without resistance.

Posterior Approach. In one patient, a posterior approach to the elbow joint was used. The skin, subcutaneous tissue, and deep fascia were incised *via* the posterior median approach; both sides of the triceps muscle were incised to expose and to protect the ulnar nerve.

Internal Fixation

After repositioning of the elbow without resistance, the original fracture fragment and its associated soft tissue were fixed to the distal humerus, such that the soft tissue could provide some stability to the repositioned elbow. Fixation was performed using a plate or tension band.

Intraoperative Evaluation

After adequate release and internal fixation, we need to evaluate the stability of the elbow joint: during the operation, the elbow joint is checked for dislocation, subluxation and friction or frictional sounds by moving the elbow joint. The elbow joint stress test is carried out under fluoroscopy for medial tension and lateral tension. At the same time, the elbow joint is observed under fluoroscopy to check whether there is wobble instability, brachial ulnar separation, radial head subluxation, and other phenomena. A drainage tube was placed, the incision was closed in layers, and the skin was closed using 4-0 sutures. Two patients were fixed with a hinged external fixator because significant instability of the elbow remained.

Postoperative Management

Patients started functional elbow exercises based on passive elbow flexion and extension and forearm rotation on the first postoperative day, and the exercises were performed to the extent of the patient's pain tolerance. In cases where an external fixator was used, the device was removed within 6–8 weeks after surgery.

Cefazolin sodium was intravenously administered on postoperative day 1 to prevent infection. After surgery, a plaster cast was applied for 1 week for external fixation, and the affected limbs were elevated and actively clenched to facilitate the reduction of swelling. At postoperative week 2, the cast was removed, and active functional exercises of the elbow joint (i.e., active elbow movements) were performed, including flexion, extension, and forward and backward rotations of the forearm. Two sessions of the exercises were performed each day, with five repetitions of flexion, extension, and rotation during each session, and a cold compress applied after each session.

In cases where an external fixation device was used, active functional exercise of the elbow was started on postoperative day 3. The elbow was alternately fixed in flexion and extension when not actively exercised, that is, the elbow was fixed in maximum flexion during the day and in maximum extension at night.

Postoperative Follow-Up and Efficacy Evaluation

Postoperative imaging data were regularly reviewed, and frontal and lateral radiographs of the elbow joint were taken to assess elbow alignment and for the presence of complications, such as heterotopic ossification, elbow dislocation, premature epiphyseal closure, and elbow deformity, and to guide functional rehabilitation training. The Mayo Elbow Performance Score (MEPS) was also used at the final follow-up to assess the elbow joint recovery (Table 1).

Statistical Analyses

IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA) was used for the statistical analyses. The measures (age, range of elbow motion, and MEPS) conformed to a normal distribution and were expressed as ($\bar{x} \pm s$). The MEPS before surgery and at the final follow-up was compared using a paired t-test. The significance level (two-tailed) was set at $\alpha = 0.05$.

Results

General Results

All children had one or more distal humerus fractures (medial epicondyle, lateral condyle, and lateral epicondyle of the humerus), including one combined with intra-articular loose bodies, three with heterotopic ossification, four with non-union fractures in and around the elbow joint, and two with articular cartilage defects (Table S1).

Intraoperative Results

Malunion or non-union fractures of the elbow joint and its surrounding tissues had significant effects on elbow joint motion and stability in all 21 patients. During surgery, internal fixation was performed to restore the stability of the elbow joint. In addition, anteroposterior capsulotomy was performed to release the elbow joint. One patient underwent removal of the intra-articular loose bodies; three patients had heterotopic ossification, of whom two underwent resection and one had a condition that did not affect the function of the elbow and thus was not further treated.

Clinical Outcomes

The mean postoperative follow-up period was 39.1 ± 23.0 (range, 10–82) months. In the preoperative period, the mean elbow extension and flexion angles were 72.2° ± 12.7° and 93.6° ± 11.1°, respectively, whereas the elbow joint ROM was 17.8° ± 8.3°. At the final follow-up, the mean extension and flexion angles were 22.7° ± 18.6° and 118.8° ± 15.4°, respectively, and the elbow joint ROM was 96.1° ± 17.4°. The differences in the preoperative and postoperative ranges of motion, flexion angles, and extension angles of the elbow joint were significant ($p < 0.01$). Meanwhile, the rotational ROM of the elbow joint was 144.7° ± 19.3° before surgery and 147.9° ± 20.1° at the final follow-up; the difference between them was not significant ($p > 0.05$).

The MEPS at the final follow-up was 78.57 ± 14.24, which was significantly higher than that in the preoperative period (29.76 ± 10.89), and the excellent rate was 81% (Table 1, typical cases are shown in Figure 1).

Complications

Complications, such as ulnar nerve symptoms, recurrent heterotopic ossification, elbow joint infection, vascular injury, or premature closure of the epiphyseal plate, were not observed during the postoperative follow-up.

Discussion

According to the present results, although the duration of elbow dislocation in children is very long, the long-term follow-up shows that the elbow function of children can be greatly improved and satisfactory results can be obtained after adequate elbow arthrolysis, restoration of the normal anatomical relationship of elbow joint, and reconstruction of elbow joint stability. This may be related to the physiological characteristics of children.

Pathological Features

Elbow dislocation in children is uncommon. Henrikson *et al.* reported an incidence of only 3% among all cases of elbow injuries in children. If not treated properly and promptly, elbow dislocation will inevitably result in severe loss of elbow function and eventual pain.[1] Pathologically, chronic elbow dislocation in children usually involves subperiosteal new bone formation, leading to abnormal bony tissues surrounding the joint and abnormal soft tissue structures. The

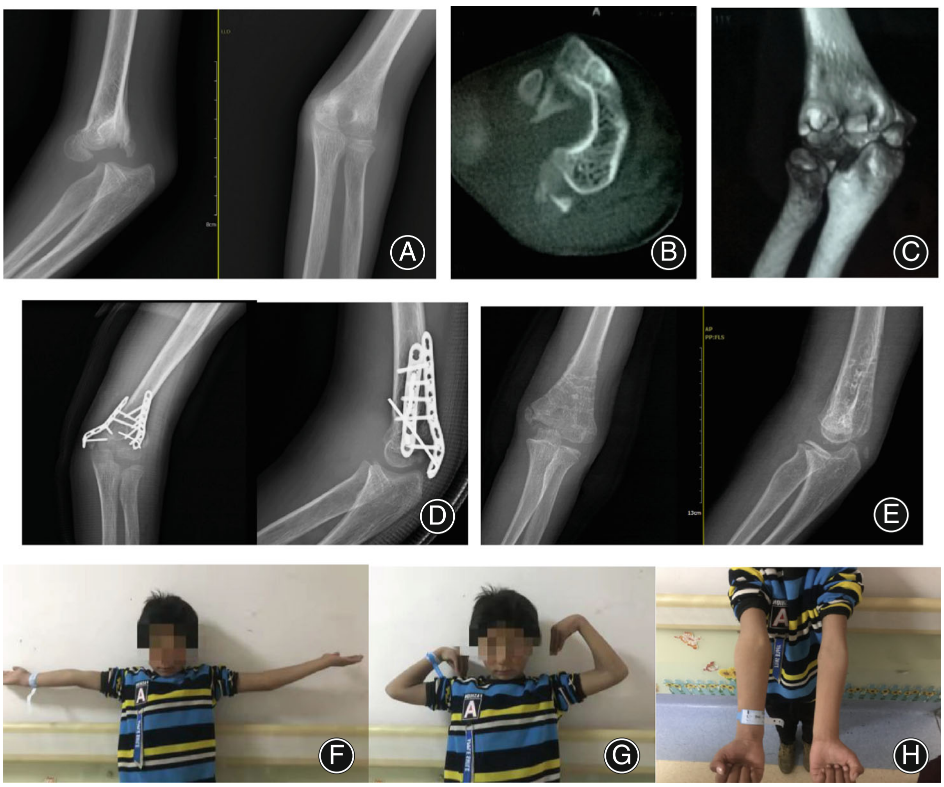

Fig. 1 A male child aged 9.7 years was injured in a fall while running and underwent surgery 7 months after the injury. (A) Preoperative frontal and lateral radiographs of the elbow joint. (B, C) A preoperative transverse CT image and a three-dimensional reconstruction image of the elbow joint suggesting chronic elbow dislocation with malunion of the medial and lateral epicondyles of the humerus and development of osteophytes. (D) Postoperative radiographs of elbow joint reduction, reduction and internal fixation of the medial and lateral epicondylar malunion, and elbow release. (E) The child's elbow joint had good stability, and there was no heterotopic ossification on the frontal and lateral radiographs taken at the final follow-up. (F–H) Elbow joint function at the final follow-up (35 months after surgery)

abnormal bony tissues include periarticular heterotopic ossification and articular osteophytes, and the abnormal soft tissues include contracted and thickened joint capsule and collateral ligament scarring. These are the primary pathological factors for elbow stiffness following chronic elbow dislocation in children.[4] At the anatomical level, elbow stiffness following chronic elbow dislocation is caused primarily by intra-articular and/or extra-articular capsular factors. Intra-articular capsular factors include joint capsule contracture and articular osteophytes, whereas extra-articular capsular factors include heterotopic ossification and trans-articular bone bridging. Intracapsular stiffness in the elbow joint can be secondary to extracapsular stiffness.[5] In addition, Morrey[6] indicated that intracapsular stiffness is always accompanied by joint capsule contracture.

Pathogenesis

Chronic elbow dislocation with extremely severe stiffness in children is a typical mixed form of stiffness dominated by intra-articular stiffness in the joint capsule. Its primary pathogenesis is a high-energy injury resulting in elbow dislocation with concomitant intra- or peri-articular fractures. Non-union and malunion of the intra-articular cartilage or periarticular fractures are caused by impaired early joint alignment or recurrent dislocation after early reduction due to elbow joint instability. Over time, misalignment of the humeroulnar and humeroradial joints, intra-articular adhesions, resorption and loss of the articular cartilage, contracture of periarticular soft tissues and ligaments, joint hyperplasia, and heterotopic ossification gradually appear, which eventually leads to extremely severe stiffness of the elbow joint. In this study, 21 children had distal humerus fractures in addition to chronic elbow dislocation, including one child with intra-articular loose bodies, three with heterotopic ossification, four with non-union fractures in and around the elbow joint, two with articular cartilage defects, and 13 with malunion fractures. Elbow dislocation in children rarely affects the superior radioulnar joint, and the probability of involvement of the rotational function of the elbow joint is low; thus, the difference in the rotational ROM of the elbow joint before surgery and at the final follow-up was not significant in this study.

Surgical Plan Selection

Speed *et al*. reported that open reduction *via* a posterior approach within 3 months of elbow dislocation in children resulted in stable reduction with better long-term results.[7] However, the treatment of chronic elbow dislocation with extremely severe stiffness in children 3 months after the initial injury has not been reported in the literature. One of the inclusion criteria in our study was a history of trauma with duration of >3 months; however, the actual duration was 6–14 months. There are many approaches for open arthrolysis of the elbow, including a posterior medial approach, a lateral approach (modified Kocher approach), a lateral plus medial (Hotchkiss) approach, and an anterior approach, all of which are appropriate for releasing elbow stiffness.[8] Ruan *et al*.[9] treated 31 patients with post-traumatic elbow stiffness using elbow arthrolysis with a follow-up period of at least 4 years. After surgery, the patients' mean elbow joint ROM improved from 49° to 108°, and the mean MEPS improved from 67.9 to 93.7. Based on the experience with open arthrolysis of elbow stiffness in adults, a single approach with a wide range of dissection can easily lead to subcutaneous hematoma and cause posterior adhesions and scar contracture. By contrast, if a dual medial and lateral approach is used, the lateral approach can be used to manage contracture and obstruction in the anterior aspect of the elbow joint. Meanwhile, the medial approach can be used to release contracture and obstruction of the ulnar nerve and posterior aspect of the elbow joint. This also reduces the incidence of subcutaneous hematoma.[10] For pediatric patients with elbow trauma herein, we primarily used lateral exposure (modified Kocher approach) combined with medial elbow exposure (Hotchkiss approach) because the posterior elbow approach has a greater effect on the extensor apparatus and is prone to forming adhesions and affecting elbow function. Generally, if patients have trans-articular heterotopic ossification on the anterior side of the elbow, anterior elbow incision is preferred. If elbow stiffness factors are predominantly posterior in older children, posterior elbow incision is considered.

Characteristics of Surgery in Children

The goal of surgery in children with chronic elbow dislocation with extremely severe stiffness is to release the adhesions and to restore the stability of the elbow joint. The approach for restoring elbow stability in children with chronic elbow dislocations differs from that in adults, where complex elbow fracture dislocations are repaired *via* fracture fixation and ligament repair to restore elbow stability and to achieve early postoperative functional exercise of the elbow joint,[11] with hinged external fixation to enhance elbow stability if necessary.[12] Osborne and Cotterill[13] proposed a method for repairing the elbow capsule and lateral collateral ligaments to restore the stability of the elbow joint. Children have tendons and ligaments that are five to eight times stronger than the epiphysis owing to their unique physiological and structural characteristics; therefore, elbow dislocations in children rarely present as simple tendon or ligament ruptures, but more often as avulsion fractures at the tendon or ligament attachment sites.[14] Even in older children, the tendons and ligaments that are ruptured after dislocation are connected by small bone fragments or thick periosteum at the attachment site. Therefore, ligament repair is not necessary in most pediatric cases, and only the necessary treatment of the fracture is required to restore the stability of the elbow joint. Notably, the avulsed bone fragments or periosteum at the tendon or ligament attachment site is highly susceptible to the formation of organized tissue or even bone tissue after elbow dislocation. The longer the time since dislocation, the greater the morphological changes in the bone fragments and the greater the changes in the tension of the tendons and ligaments, making it more difficult to conduct surgical repair and reconstruction. For bone fragments (bone tissue) that no longer have their normal anatomical form, our experience has been to trim the bone fragments (bone tissue) appropriately and then fix them in the proximal anatomical position to maintain the stability of the elbow joint and to meet the needs of postoperative functional exercise.

Although open arthrolysis is easy to comprehend and reliable for elbow release in adults, it is highly invasive, involves much postoperative hemorrhage, and is prone to yielding elbow adhesions and recurrence of heterotopic ossification, as well as complications, such as failure of surgical incision healing, elbow infection, and ulnar nerve injury.[3,15–20] In our study, all children underwent open arthrolysis of the elbow joint and robust internal fixation of the fracture, as necessary. At the final follow-up, the elbow mobility increased by a mean of 78.3° compared with that before surgery, the MEPS increased by a mean of 48.81, and none of the children had complications, such as failure of surgical incision healing, elbow joint infection, nerve injury, or premature closure of the epiphyseal plate (Figure 1). The excellent rate was 81%. These findings suggest that the risk of complications in our pediatric patients who underwent arthrolysis was low, which may be related to the strong capacity for repair during child growth and development.[21] Notably, two patients (Table S1: Case 9 and case 21) were found to have unstable elbow joints even after open arthrolysis and necessary robust internal fixation of the fracture owing to their older age and longer time since dislocation, and fixation was achieved using a hinged external fixator. After surgery, the functional recovery of the elbow joint was significantly faster in these two patients, which was probably related to the fact that the hinged external fixator enhanced the elbow joint stability and was more conducive to early functional exercise of the elbow joint.[22] Therefore, the aim of the surgical treatment of chronic elbow dislocation in children with severe stiffness is to restore the normal anatomical relationship and stability of the elbow joint. Open arthrolysis and internal fixation of the elbow joint are effective in treating chronic elbow dislocation with severe stiffness in children.

Strengths and Limitations

This study is the largest sample size in the literature on chronic elbow dislocation with very severe stiffness in children. It summarizes the purpose and characteristics of surgical treatment in children, and the research results are convincing.

This was a retrospective (instead of prospective) study with a small sample size, lacking the support of large-sample clinical data. Further, the follow-up period was still relatively short in some cases. Thus, long-term follow-up and further research are still required to determine whether arthritis or secondary developmental deformities will occur and whether the application of a hinged external fixator can provide better treatment efficacy at later stages.

Conclusion

Our retrospective review shows that open arthrolysis and open reduction and internal fixation of the elbow joint are effective in treating chronic elbow dislocation with extremely severe stiffness in children. It can effectively improve the function of the elbow joint by restoring the normal anatomical relationship of the elbow joint and reconstructing the stability of the elbow joint. So, reconstruction of elbow stability is as important as open arthrolysis and has a positive effect on the recovery of elbow function. Meanwhile, surgical treatment is worthwhile regardless of the duration of dislocation.

Author Contribution

Xin Liu: Conceptualization, Writing—Review & Editing, Supervision. Chi Kang: Methodology, Formal analysis, Data Curation, Writing—Original Draft. Ming Xiang: Validation, Project administration. Jinsong Yang: Data Curation, Visualization. Yuan Xiao: Methodology, Validation. Bo Ren: Validation, Formal analysis. Liwei Xie: Resources, Investigation. Renhuan Zhao: Data Curation. Wei Chen: Investigation. Zhiqiang Deng: Validation. Jiajun Ye: Investigation. Ying Zhou: Supervision. Qiang Sun: Data Curation.

Disclosure

The authors declare that there are no competing interests regarding the publication of the paper.

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Appendix S1. Supporting Information.

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