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ORIGINAL PAPER

Kapandji pinning and tuberosities fixation of three- and four-part fractures of the proximal humerus

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Abstract
Purpose The Kapandji pinning was initially described for the treatment of surgical neck fractures of the humerus in young patients. The aim of our study was to evaluate functional and radiological outcomes of the Kapandji modified technique in displaced complex three- and four-part fractures.
Methods From 2005 to 2009, 32 patients (23 three-part and nine four-part fractures) were included retrospectively. The mean age was 63 years old (range, 22–86), and the dominant shoulder was involved in 40 % of the cases.
Results At a mean follow up of 25 months (12–72), the mean absolute Constant score achieved 68 points (35–98) and adjusted score 80 % (47–100). Patients had an average forward elevation of the shoulder of 132° (80°–180°), an average external rotation of 36° (0°–90°), and an average internal rotation to the level of L1 (sacrum to the level of T6). The older the patients were the worst was the active anterior elevation recovery (r=−0.3; p=0.01). Reduction and fixation of initial varus-displaced fractures was not as reliable as in valgus. In eight cases (25 %), K-wire migrations were observed and were correlated with age over 70 years old (p=0.001). Two partial osteolysis of the greater tuberosity and two avascular necrosis of the humeral head (one was associated with a non-union) were identified. Moreover, three patients developed adhesive capsulitis.
Conclusion The Kapandji technique with fixation of tuberosities provides satisfactory results for the treatment of complex proximal fractures of the humerus. However, we do not recommend this technique for patients older than 70 years and in cases of varus displaced fractures.

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Introduction

Proximal humeral fractures account for 5–10 % of all fractures and represent the third most common fracture in the elderly patients [3, 23]. The decision-making process for treatment depends on many variables regarding fracture patterns, including age and activity level of the patient. A number of these fractures are minimally displaced and require non-operative management [16]. Surgical procedures remain under controversial discussion and include fixation with locking or nonlocking plate, pinning, nailing, and shoulder replacement [12, 17, 24].

In 1989, Kapandji described his technique of centromedullary pinning for the treatment of displaced surgical neck fractures in young patients, with divergent K-wires introduced at the "V" deltoid level [9]. Few authors are experienced in this technique and have reported the results, including simple and complex fractures [5, 13, 14, 19, 28]. The purpose of our study was to evaluate clinical and radiographic outcomes of complex three- or four-part proximal displaced humeral fractures treated with Kapandji pinning and additional fixation of the tuberosities.

Patients and methods

Inclusion criteria

This was a retrospective study conducted in our department from 2005 to 2009. Patients with displaced three- or four-part proximal humeral fractures' according to the Neer classification, treated operatively with Kapandji pinning and complementary fixation of tuberosities were included [9, 16]. A minimum radiographic and clinical follow-up of 12 months was required. Patients with fractures extending into the humeral shaft or into the articular surface (head split

fractures) and patients treated with other methods of fixation or with shoulder replacement were excluded from the study.

During the period of the study, 101 three- or four-part proximal humeral fractures were treated operatively in our department by multiple senior surgeons. Twenty-one arthroplasties, 18 anterograde nailings, 12 platings and ten isolated pinnings were excluded based on study criteria. Forty fractures fixed with Kapandji pinning technique and complementary fixation of tuberosities were selected. Eight patients were lost for follow-up, leaving 32 patients available for the clinical and radiographic analysis. All patients signed consent to allow the process of clinical and radiographic study.

Patients

There were ten males and 22 females with a mean age at the time of the surgery of 63 years (range 22–86). The right shoulder was involved in 17 cases and the dominant side in 13 (40 %). Twenty-one patients were retired, six had heavy manual labour occupations, and five a light-manual labour. In 25 cases, the fracture occurred following a fall from a height.

Twenty-three three-part and nine four-part fractures of Neer classification were diagnosed according to CT-scan analysis by a senior surgeon. There was one case of fracture-dislocation in a four-part fracture. All three-part fractures involved the greater tuberosity. The displacement of the humeral head related to the humeral shaft (α angle) was considered in varus for six cases and in valgus for 15 (Fig. 1). In the remaining 11 cases, α angle was almost normal ($30° < \alpha$ angle $<50°$) [1].

Surgical procedure

The surgical procedure was performed at 1.9 days on average (range zero–15) from the initial trauma. Under general anaesthesia, patients were placed in a beach-chair position. The upper limb was prepped and draped in a sterile fashion, free of the table. C-arm fluoroscopy was positioned in order to obtain orthogonal imaging of the proximal part of the humerus during the procedure.

The first step consisted of pinning, whereby the deltoid "V" insertion was identified clinically and confirmed under fluoroscopy. Then, a short approach (4 cm) was performed directly toward the humeral shaft, dividing brachial muscle fibres, and a hole of 6 mm was created with drills of increasing diameter. During the exposure of the shaft, bent retractors are never placed at the back of the shaft to avoid radial nerve damage. Three or four non-threaded K-wires of 2-mm diameter were prepared in a "double bent fashion" (proximal 10 mm is bent by 45° followed by a smooth gentle curve in the same direction of the next 10 cm).

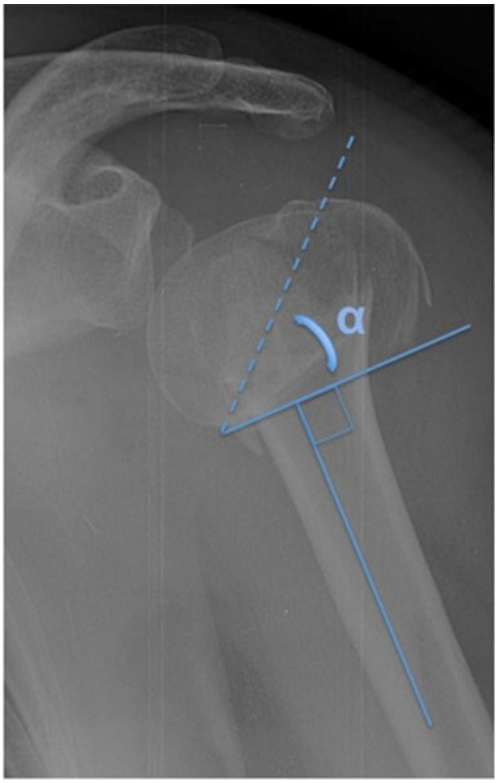

Fig. 1 α angle measured on AP view as the angle between the perpendicular line to the shaft axis at surgical neck level and the anatomical head axis

Then, wires are inserted in the medullary canal and pushed up to the level of the fracture.

For 11 cases, a percutaneous reduction of the humeral head was performed with a spatula and the K-wires were placed in the subchondral bone in a divergent fashion. For the remaining 21 cases, a trans-deltoid anterior-superior approach was performed. Heavy non-absorbable sutures were passed through the rotator cuff tendon at the bone–tendon level to control the tuberosities for reduction. The long head of the biceps was tenodesed or tenotomised in 20 cases and left intact in 12. When the humeral head was impacted in valgus, the reduction manoeuver was gently performed through the fracture site, preserving the medial edge continuity of the humeral head with the shaft. If the humeral head was displaced in varus, the reduction was obtained by combination of pulling the shaft downward and pushing upward the lower part of the humeral head. In case of three-part fractures with an intact lesser tuberosity, the traction suture passed through the subscapularis tendon allowed reduction of internal rotation and varus of the head. After fluoroscopic control of the quality of the reduction, the K-wires were placed into the subchondral bone under visual control and in a divergent direction to maintain the reduction. In case of metaphysal cancellous bone impaction, bone substitutes of calcium phosphate (SBM®, Lourdes, France)

were used to fill the bone defect. This was performed in 15 cases.

In the following step and in case of open surgery, the tuberosities (greater ± lesser tuberosity) were reduced and fixed to each other and to the humeral shaft with a tension band technique using number 5 non-absorbable sutures alone (11 cases) or combined with 4-mm diameter screws (ten cases). In 11 cases of percutaneous reduction, a direct screwing of the greater tuberosity was performed under fluoroscopic control.

At the end of the procedure, the K-wires were carefully bent to 90° at their entry point ("V" deltoid level) to avoid retrograde migration, cut at 1 cm of the humeral shaft, and left beneath the skin surface.

Postoperatively, patients were immobilized in a sling for six weeks and a program of passive rehabilitation was delayed to three weeks. Active motion and rotation was allowed after six weeks.

Clinical and radiological evaluation

Pre and early postoperative information were collected from chart review. Active shoulder motion, including forward elevation, external rotation on the sides, and internal rotation as the spinous process reached by the thumb were measured by an independent observer. Clinical results were evaluated with the Constant and Murley score, adjusted by age. A self-satisfaction rating scale was used regarding subjective results (very satisfied, satisfied or disappointed).

Plain radiographs consisting of anterior posterior (AP) views in neutral rotation and lateral scapular views were analysed post-operatively at three weeks, six weeks, three months and at the last follow-up. The quality of the fracture reduction, secondary displacement, hardware migration, the quality of bone healing and the presence of humeral head necrosis were investigated. At six weeks, the α angle was measured and the greater tuberosity position was assessed—it was considered correctly reduced when the greater tuberosity was visible on the anterior posterior view in neutral rotation, between 5- and 10-mm under the humeral head, and with a lateral offset between 15 and 20 mm (Fig. 2) [1, 8].

Statistical methods

Univariate descriptive statistical analysis was performed. The distribution of the data was analysed with the Agostino–Pearson test. Means were compared in the different groups of patients; for paired results a t-test was used, whereas unpaired results were compared with the Mann–Whitney test. Pearson's correlation coefficient was used to determine whether two variables were significantly related. Relations between two qualitative variables were tested with the chi-squared test or Fisher's exact test. The significance level was set at 0.05. Statistical analysis was performed with the SAS software (SAS Institute, Cary, North Carolina).

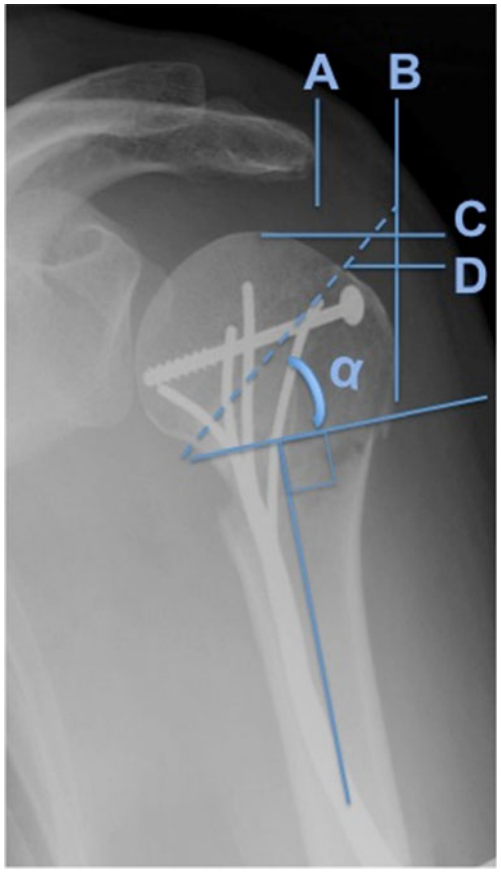

Fig. 2 Criteria of the radiologic evaluation. *A–B* lateral offset of the greater tuberosity; *C–D* greater tuberosity height

Results

Overall clinical results

At an average of 25 months follow-up (range, 12–72), the mean absolute Constant score was 68 points (range, 35–98 points) and adjusted Constant score 80 % (range, 47–100 %) (Fig. 3). Patients had an average forward elevation of the shoulder of 132° (range, 80–180°), an average external rotation of 36° (range, 0–90°), and an average internal rotation to the level of L1 (range, sacrum to the level of T6). Adjusted Constant score showed no significant differences comparing clinical outcomes of three-part vs four-part fractures, varus vs valgus displaced fractures, or percutaneous vs open treatment (respectively, $p=0.61$; $p=0.35$; $p=0.13$). However, the older the patients were the worst were the active anterior elevation recovery ($r=-0.3$; $p=0.01$) (Fig. 4). Subjectively, patients were satisfied or very satisfied in 75 % of cases.

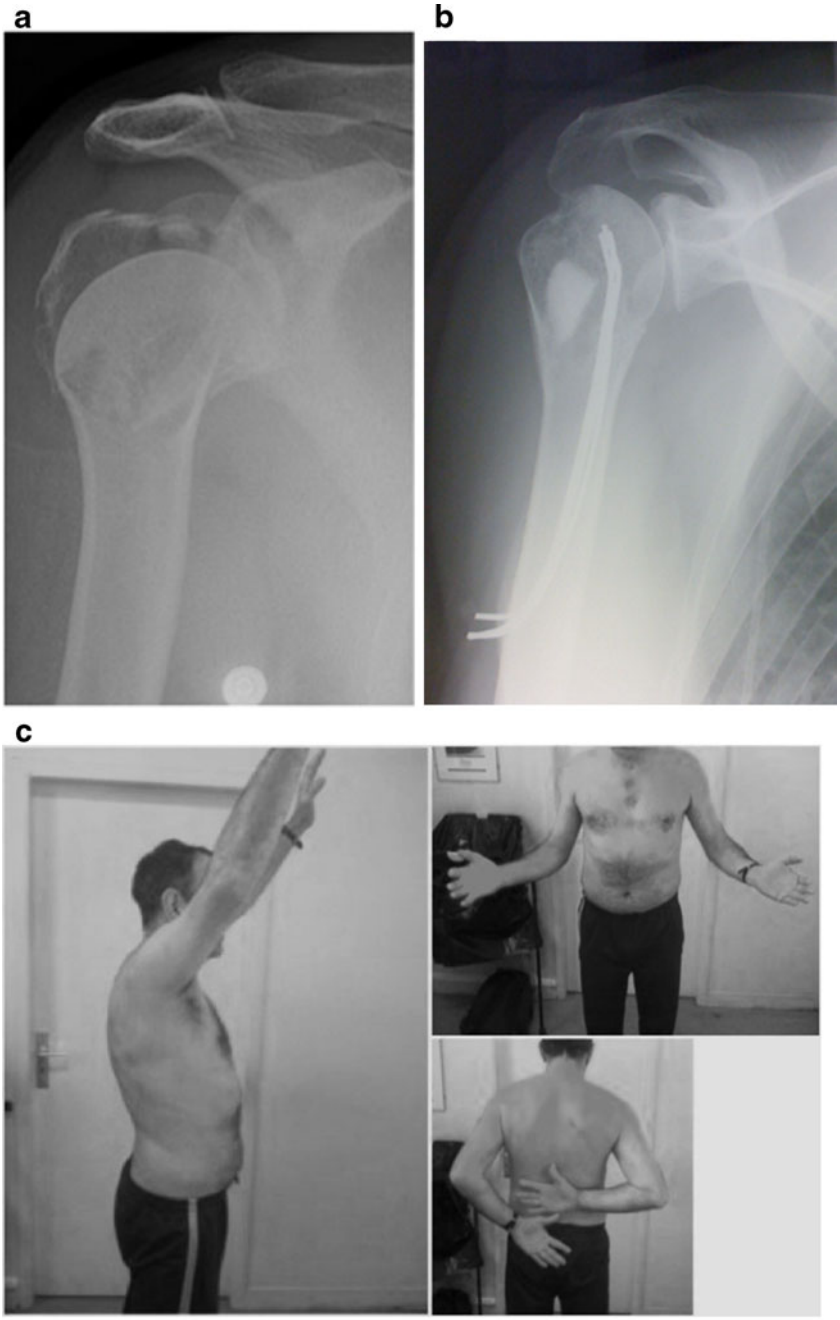

Fig. 3 Anteroposterior view of four-part displaced valgus fracture in a 55-year-old patient. Radiographic results at three-years follow-up after open reduction (anterio-superior approach) and stabilisation according to the Kapandji modified technique. A bulk grafted bone substitute was used and tuberosities were fixed with a tension band technique. Range of motion at three-years follow-up. Absolute Constant score was 91 points

Complications and reoperations

In eight cases (25 %), K-wires migrated into the humeral head during the healing process with subacromial impingement that required early removal. This complication was observed in five cases of three-part fractures and three cases of four-part fractures (p=0,22), whereas the displacement was initially in varus in two and in valgus in six. Migration was correlated with an age greater than 70 years (p=0.03). In 17 other cases (53 %), K-wires removal was necessary because of patient discomfort at the "V" deltoid level at nine months on average (range, 2.5–20) postoperatively.

Three patients (10 %) developed adhesive capsulitis that required physiotherapy treatment. In this group, the mean adjusted Constant score was 68 % at the last follow-up.

In one case, a revision with a reverse shoulder arthroplasty was necessary to treat avascular necrosis of the humeral head with fracture non-union associated with a poor clinical outcome. This was a 68-year-old patient with a four-part impacted valgus fracture who achieved an adjusted Constant score of 54 % before revision. At last follow-up, the score increased to 65 %.

No infection or neurologic complications were reported.

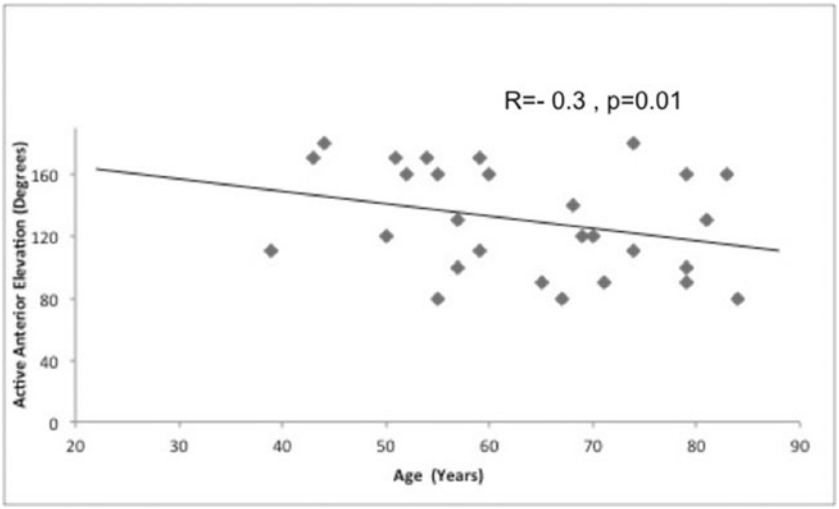

Fig. 4 Correlation between age and active anterior elevation at follow-up

Radiographic results

At six weeks postoperatively, fracture reduction was evaluated on AP view. A secondary displacement was identified in nine cases (28 %), associated with pin migration in eight. The average α angle decreased from 50° (range, 15–110; ± 34) preoperatively to 46° (range, 20–70; ± 11) postoperatively (p=0.32). A residual displacement deformity was identified in three out of six cases of varus-displaced fractures, whereas all 15 valgus-impacted fractures were correctly reduced (p=0.04) (Table 1).

The greater tuberosity was considered in an uncorrected position in seven cases, which was correlated with a worse Constant score (p=0.04). In four out of these seven cases, the greater tuberosity was too low or too medialized.

All but one fracture healed at an average of three months (range, one to six). Two partial necrosis of the humeral head were identified on standard X-rays at last follow-up—one required a revision procedure with a reverse shoulder replacement as previously reported and the other kept a satisfactory outcome despite this radiographic finding.

Discussion

Our study confirmed that Kapandji pinning with reduction and stable fixation of the humeral tuberosities was a reliable option in complex three- and four-part proximal humeral fractures. However, the results were correlated to the patient's age, i.e. in patients over 70 years, secondary displacement and K-wires migrations were frequent with less favourable clinical outcomes.

In the original study, Kapandji [9] reported 86 % satisfactory results at a mean follow-up of ten years. However, this series included only surgical neck fractures in young patients. Monin et al. [14] used Kapandji pinning in 13 complex three- or four-part factures; 40 % of pin migration and 10 % of secondary displacement were reported at a mean follow-up of 45 months. Later, Le Bellec et al. [13], reviewing 31 cases treated with the Kapandji method for 19 two- and 12 three-part proximal humerus fractures, reported 26 % of pin migration, increasing to more than 40 % in patients older than 60 years. More recently, El-Alfy [5] proposed to introduce the K-wires into independent holes to avoid the problem of migration. He reported 77 % good or excellent results and only one case of pin migration in a series of 18 cases. However, there were only five cases of three-part fractures in this study. Interestingly, Ogawa et al. [19] used the same modification in ten four-part valgus-impacted fractures and did not report hardware migration. The results were excellent in eight patients and less favourable in two because of secondary avascular necrosis of the humeral head. This modification of the original technique of pinning needed to use 2.4-mm diameter K-wires (bigger than we used) inserted into three independent drill holes ranging from 3.0 to 3.2 mm. Even if it was not

Table 1 Comparative results

Variable	Preoperative	At 3 months
Mean α angle (degrees)	50° (15–110; ± 34)	46° (20–70; ± 11)
Valgus displacement α angle < 30° (number of patients)	15	0
Varus displacement α angle > 50° (number of patients)	6	3
30° < α angle < 50° (number of patients)	11	29

reported, this method could increase the theoretical risk of iatrogenic fracture in a postage-stamp pattern of the humeral shaft.

Direct percutaneous pinning with straight K-wires has also been proposed in association with closed reduction [10, 20, 21]. Resch et al. [20] reported the results of three- and four-part fractures treated according to this technique. At 24 months average follow-up and among 27 patients, all three-part fractures demonstrated good to very good functional results without avascular necrosis. However, the age of the patients in this group was 54 years on average and no patient was older than 68 years. Recently, with a similar technique Roberts et al. [21] identified more hardware problems with patients older than 60 years. Osteoporosis, which is frequently identified at the upper part of the humerus in elderly patients, partly restricts the use of these techniques based on pinning fixation, whatever the method used [11, 15]. Locked plate used to fix the different fragments would theoretically enhance the primary stability of reduced fractures, but several authors reported 5–15 % rate of screws cutout [26]. Nailing with angular stable locking screws should share the advantage of minimal dissection and biomechanical properties with pinning and plating, respectively [26]. However, conservative treatment should be considered in elderly patients with low functional demand as it provides good quality of life results without complications [27].

Radiographic analysis has shown in our study that reduction of varus-displaced fractures does not seem to be stable over time with the technique of Kapandji. This problem has been identified with other modes of fixation [6, 7, 18, 20, 25]. Nevertheless, numbers of plates or nails offer the possibility of additional screws at the lower part of the humeral head, to restore the stability of the medial column when comminution prevents an anatomic reduction with cortical contact. In the case of valgus-displaced fractures, the cancellous bone is usually compacted in the epiphysis, leaving a void after anatomical reduction of the humeral head. Because centro-medullary pinning is low profile hardware, addition of bone substitute is mandatory to improve humeral head stability and reduce the risk of medialization of the greater tuberosity [4, 22].

Independently of the technique of fixation used, anatomic reduction of the tuberosities is a major predictive factor of the outcomes, and should increase the stability of the humeral head in case of four-part fracture according to the "Eggshell model" of Hertel [2, 24, 26]. Percutaneous reduction and screwing fixation remains an option to avoid soft tissue dissection, to preserve periosteal links and to decrease the risk of damage to the blood supply of the humeral head [20]. In our series, this was possible in only one third of fractures and we preferred the anterior-superior approach to favour the quality of reduction and to secure tuberosities in elderly patients with osteoporotic bone [2].

The limitation of our study was related to the retrospective type of the study as well as the short-term follow-up. No control group was designed to compare the Kapandji technique to other types of treatment. Moreover, we acknowledge that the method used to fix tuberosities was variable (open or percutaneous surgery, tension band suture, screw) which is open to criticism. However, it was the largest series evaluating the clinical and radiographic outcomes of the Kapandji pinning in three- and four-part proximal humeral fractures treated a in single trauma centre.

In conclusion, this technique showed satisfactory results for treatment of these complex proximal humeral fractures. However, hardware removal was frequently required because of K-wire migration and shoulder discomfort. Moreover, this technique must be carefully indicated in case of initial varus-displaced fractures. Finally, results were less favourable in patients older than 70 years and we do not recommend this technique for this patient population.

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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