Percutaneous pinning of three- or four-part fractures of the proximal humerus in elderly patients in poor general condition: MIROS[®] versus traditional pinning

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Abstract

Purpose Elderly subjects often have fractures of the proximal humerus, which may be difficult to manage in patients in poor general condition. The MIROS is a new percutaneous pinning device allowing correction of angular displacement and stable fixation of fracture fragments. We evaluated the results of percutaneous fixation of three- or four-part fractures of the proximal humerus of patients in the American Society of Anesthesiologists physical status three or four treated either with MIROS or traditional percutaneous pinning (TPP).

Methods A total of 31 patients treated with MIROS and 27 undergoing TPP were enrolled in the study. Pre-operatively anteroposterior and transthoracic or axillary radiographs were obtained in all cases and computed tomography scans in patients with the most complex fractures. Follow-up evaluations were carried out at three, six, 12 and 16 weeks, and six months, one year and two years postoperatively, using the Constant Score (CS) and subjective shoulder value (SSV) methods.

Results Of the 58 patients, 52 could be evaluated at all follow-ups. In both three- or four-part fractures there were significantly higher CS and SSV scores in the MIROS compared to the TPP group at all the late follow-ups. Lower rates of deep infection, pin tract infection and pin mobilisation were found in the MIROS group ($p < 0.001$). In both groups there was a significant association between the final result (CS) and either the type of fracture or complications ($p < 0.001$).

Conclusions The MIROS resulted in better clinical results and less complications than TPP in elderly patients. This method, however, may not be indicated for younger patients in good general condition.

Introduction

Treatment of three- or four-part fractures of the proximal humerus in elderly patients is still controversial. While a few studies reported that non-operative management is associated with poor results [1, 2], a recent prospective, but not controlled, trial found it difficult to demonstrate a significant advantage of surgical over non-operative management [3]. Consistent with the findings of the latter study is the observation that the results of various surgical treatments, such as closed reduction and percutaneous pinning [4, 5], plate fixation [6, 7] and hemiarthroplasty [8], may be unpredictable. However, the fracture pattern, amount of displacement of the fragments, bone stock of the upper humerus, pre-existing rotator cuff disease or arthrosis and the patient's age and general condition are important factors in the choice of treatment.

For many years, worries over possible avascular necrosis of the humeral head have led hemiarthroplasty to be the

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treatment of choice for displaced three-part and especially four-part fractures. In the last two decades, better knowledge of the vascular supply to the humeral head has shifted the surgical choice towards procedures of reduction and internal or external fixation for most three-part and even four-part fractures [5, 6, 9–12].

Percutaneous techniques may allow displaced fractures of the proximal humerus to be reduced and stabilised by Kirschner wires (K-wires) alone or wires clamped into a locking device. The advantages of these techniques are not only the possible preservation of vascular supply to bone fragments, but also no blood loss and the possibility of surgery under brachial plexus block. The latter prerogatives may be of considerable importance when treating patients in poor general condition, such as those in American Society of Anesthesiologists (ASA) physical status (PS) three or four [13].

The MIROS (Minimally Invasive Reduction and Osteosynthesis System®) is a recently introduced device for treatment of fractures of the upper limb, particularly those of the proximal humerus. It allows correction of angular displacement and fixation of fracture fragments by means of elastic K-wires locked in a metallic clip placed externally on the skin. We assumed that the MIROS might provide greater fracture stability and less complications with respect to traditional percutaneous pinning (TPP). A prospective study was thus carried out to compare the MIROS to TPP for the treatment of three- or four-part fractures of the upper end of the humerus of elderly patients in ASA PS 3 or 4.

Materials and methods

Between 2007 and 2009, ASA PS three or four was assigned to 58 consecutive patients admitted at two hospitals of a single town for fracture of the proximal humerus. In one hospital the patients were treated with the MIROS, while in the other TPP was performed. There were 37 women and 21 men with a mean age of 76 years (68–93), the patients of the two groups being matched for mean age, sex, mean ASA PS score and type of fracture (Table 1). A concomitant fracture was present in five and three patients in each group, respectively.

Patients underwent true anteroposterior and transthoracic radiographs, and an axillary view when the arm could be abducted. Radiographs were evaluated by two of the authors with a special interest in shoulder trauma and classified according to the Neer system [14]. In the presence of complex fractures, computed tomography (CT) scan with 3-D reconstructions was performed. In no patients were there local vascular or neural complications. Excluded from the study were patients with a fracture extending to the humeral diaphysis or the articular surface of the humeral head and

Table 1 Patients' details

	TPP	<i>p</i> values	MIROS
Enrolled	27	–	31
Mean age±SD (range)	78.3±11.3 (68–89)	0.8	80.7±7 (76–85)
Three-part fracture	15 (55.5%)	0.5	18 (58.1%)
Four-part fracture	12 (44.5%)	0.9	13 (41.9%)
ASA PS	3/15 pts; 4/12 pts		3/15 pts; 4/16 pts
Complete follow-up	26	–	28
Three-part fracture	15	0.2	17
Four-part fracture	11	1	11
Concomitant fractures	3 (11.5%)	0.1	5 (17.8%)

those with no active motion of the arm due to previous cerebrovascular diseases. Patients under study gave their informed consent to the operation.

The patients of both hospitals underwent clinical evaluation and shoulder radiographs at three, six, 12 and 16 weeks. In each hospital they were assessed by an orthopaedic surgeon not involved in the patient's management. At six, 12 and 24 months the patients of both groups were assessed by the examiner who had carried out the earlier evaluations of the patients in the TPP group. Of the original patients, six were lost to the latest follow-up (two had died and four did not attend for assessment), thus leaving 28 patients in the MIROS group and 26 in the TPP group. The number of three-part, or four-part, fractures was similar in the two groups (Table 2). The shoulder function was evaluated using the Constant Score (CS) method [15]. The patients were also asked to rate the result of surgery with the subjective shoulder value (SSV) method [16]. Measurement of the range of motion was performed in the standing position using a goniometer and that of the abduction strength by the Micro-FET dynamometer (Hoggan Health Industries, West Jordan, UT, USA). Radiographic evaluation included true anteroposterior and axillary views of the shoulder.

Operative techniques

The MIROS (Technovare, Europa Trading s.r.l., Anagni, Italy) consists of four 2.5 mm thick and 50 cm long stainless steel or titanium wires the end of which is introduced into a metallic clip (Fig. 1). The latter has a diameter of 20 mm and contains a screw that is tightened to lock the wires.

The patient, after supraclavicular brachial plexus block, was placed supine with the head of the operating table raised to 30°. Before inserting the K-wires, attempts were made to reduce the fracture by manipulation. The first K-wire was introduced into the greater tuberosity and then pushed down

Table 2 CS and SSV scores at all follow-up evaluations in our cohorts of patients

		TPP Average±SD	<i>p</i> values	MIROS Average±SD
6 months CS	Three-part	45±7 (30–58)	0.02	57±12 (45–68)
	Four-part	38±11 (28–59)	0.01	50±11 (35–64)
	Mean	41.5	0.016	53.5
6 months SSV	Three-part	60±10 (30–70)	0.023	70±15 (40–80)
	Four-part	55±5 (35–60)	0.038	65±5 (50–70)
	Mean	57.5	0.032	67.5
12 months CS	Three-part	55±11 (42–64)	0.04	63±8 (47–70)
	Four-part	47±9 (28–59)	0.037	55±12 (38–68)
	Mean	51	0.039	59
12 months SSV	Three-part	75±10 (60–80)	0.023	90±15 (70–100)
	Four-part	70±10 (60–90)	0.018	85±5 (65–95)
	Mean	72.5	0.2	87.5
24 months CS	Three-part	53±9 (45–65)	0.01	62±11 (48–70)
	Four-part	50±10 (40–60)	0.03	58±13 (39–66)
	Mean	51.5	0.02	60
24 months SSV	Three-part	75±10 (60–85)	0.023	90±15 (70–100)
	Four-part	70±10 (60–90)	0.01	90±5 (75–95)
	Mean	72.5	0.015	90

to the lateral epicondyle. The second cranial K-wire was inserted into the largest part of the humeral head and directed to the medial epicondyle. When inserting these K-wires attention was paid to avoid subacromial impingement by slightly bending the wires after they were introduced perpendicularly to the skin. The remaining two K-wires were inserted from the proximal humeral metaphysis with a cranial direction until they reached the subchondral bone of the humeral head (Fig. 1). Then, further bending of the four K-wires was carried out to lock them into the external clip, which was placed at least 2 cm from the skin of the deltoid area. Once the clip was blocked, it was possible to slightly correct the varus or valgus position of the humeral head by compressing or distracting the K-wires into the metallic clip. They were then cut and the screw inside the clip was tightened (Fig. 2). Post-operatively a sling was applied. The MIROS was removed five or six weeks after the operation (Fig. 3)

Fig. 1 Fluoroscopic view after insertion of the four K-wires of MIROS. The *numbers* indicate the sequence with which the wires are inserted. The *arrow* points to the externally placed metallic clip

TPP was performed according to the technique first described by Jaberg et al. [17] using five terminally threaded 2.5-mm Schanz pins. The edges of the pins were bent manually and left outside the skin. Post-operatively, patients wore a sling for three or four weeks. The pins were removed five or six weeks after the operation.

Fig. 2 Photograph taken after implantation of the MIROS, showing the external part of the system

Fig. 3 A 74-year-old woman with a four-part fracture of the upper humerus and ASA PS four treated with MIROS. **a, b** Preoperative 3-D CT scans. **c** Post-operative anteroposterior radiograph. **d** Anteroposterior radiograph obtained at the six-month follow-up

Post-operative treatment

In the MIROS group pendulum exercises were begun a mean of four days after surgery and passive assisted exercises two weeks post-operatively. Passive motion was progressively increased depending on the patient's tolerance. In the TPP group, passive shoulder motion was started three or four weeks depending on the type of fracture and active motion five or six weeks after surgery.

Statistical analysis

Fisher's exact test was used to compare the proportions and Student's *t* test for average values; *p* values <0.05 were deemed to be statistically significant. Multiple regression analysis was performed to identify potential associations between dependent variables (CS and SSV) and independent variables (type of fracture, complications).

Results

The mean operative time was 37.3 min (range 19–44) in the MIROS group and 40.1 min (range 32–125) in the TPP

group. The mean fluoroscopy time was 76 s (range 32–125) and 50 s (range 40–68), respectively ($p < 0.001$).

The mean CS and SSV scores were significantly higher in the MIROS group compared to the TPP group at all late follow-ups (Table 2). The mean range of motion was consistently greater in the MIROS patients with either a three-part or four-part fracture (Table 3); the differences were found to be consistently significant except for the three-part fracture pattern at the 24-month follow-up. The mean abduction strength was greater in the MIROS group at the six, 12- and 24-month follow-ups (Table 3).

The overall complication rate was 10.7% in the MIROS group and 26.9% in the TPP group (Table 4). The intra-operative complications were a perforation of the humeral head in one patient undergoing TPP and of the humeral head and the glenoid fossa in one of the MIROS group. Other complications were pin mobilisation or displacement, local deep infection and avascular necrosis of the humeral head. One or two pins displaced, that is partially came out from the humerus, in five patients in the TPP group; they were removed with no loss of reduction of the fracture. In one patient in the MIROS group there was a moderate displacement of pins within the upper humerus with resultant moderate loss of fracture reduction. The case in the TPP group

Table 3 Range of motion (ROM) (/40) and muscle strength (/25) in the two groups of patients

		TPP Mean±SD (range)	<i>p</i> values	MIROS Mean±SD (range)
6 months ROM	Three-part	14±3 (9–22)	0.001	30±7 (23–33)
	Four-part	12±4 (8–15)	0.001	26±5 (20–29)
6 months strength	Three-part	3±2 (1–6)	0.03	8±5 (5–15)
	Four-part	3±3 (1–7)	0.05	6±6 (3–12)
12 months ROM	Three-part	21±7 (16–29)	0.002	31±5 (23–34)
	Four-part	18±4 (14–23)	0.01	26±6 (21–28)
12 months strength	Three-part	7±3 (2–10)	0.047	10±5 (6–16)
	Four-part	4±2 (3–7)	0.05	7±2 (4–9)
24 months ROM	Three-part	30±8 (20–35)	0.056	33±6 (26–35)
	Four-part	27±12 (20–38)	0.048	32±4 (26–31)
24 months strength	Three-part	8±5 (5–12)	0.044	11±7 (6–18)
	Four-part	7±5 (3–10)	0.047	10±4 (4–14)

The figures in parentheses indicate the maximum CS for each parameter

with a deep infection was treated with antibiotics with no sequelae. Of the four patients who had avascular necrosis, three did not ask for revision surgery because their clinical condition was acceptable. In the patient in whom the severity of pain would need repeat surgery, hemiarthroplasty could not be performed because general anaesthesia was contraindicated. However, at the latest evaluations, these patients were those with the lowest CS and SSV scores in each group. A statistically significant difference between the two groups was found for overall complications, pin mobilisation and pin tract infection ($p<0.05$) (Table 4).

In both groups, the multiple regression analysis showed that the variables that influenced the CS at the latest follow-up were the type of fracture [three- vs four-part fractures ($p=0.03$)] and complications ($p<0.001$).

Discussion

The prerogatives of the percutaneous pinning techniques are of paramount importance when treating elderly patients with cardiovascular or pulmonary diseases, particularly those in ASA PS three or four, in whom general anaesthesia is very risky or clearly contraindicated. Their limitation, compared to open reduction internal fixation (ORIF), is that they may

allow a less anatomical reduction of bone fragments. However, several studies [4, 17–19] have shown that this is not a major drawback in most fractures of the proximal part of the humerus, because the clinical results can be satisfactory even in the presence of a non-anatomical reduction of the fracture.

TPP, which is the simplest technique of external fixation, has several drawbacks. In our series, the mean CS showed a limited increment from the six-month to the 24-month follow-up, the scores being 41 and 51 points, respectively. Furthermore, complications occurred in 26.9% of cases. They included pin displacement, pin tract and/or deep infection and avascular necrosis of the humeral head, i.e. the same complications that were found, in similar percentages, in previous studies on this method of treatment [17, 20]. These observations indicate that TPP should be avoided not only in patients in poor general condition, but also in those in fair or good condition who can stand general anaesthesia.

So far, two methods of percutaneous pinning with the use of a device locking the end of the pins have been described [4, 21, 22]. In one of them the locking device, called “humerus block”, is placed deep to the lateral portion of the deltoid muscle, adherent to the cortical bone of the uppermost humeral diaphysis, through a 4-cm skin incision. The device, which can lock two pins, is left on site and removed, together with the pins, after fracture healing if the patient complains of local discomfort; when needed, one or more screws inserted percutaneously can be utilized with the pins to fix single fragments [4]. The second method, called the “hybrid technique”, implies open reduction of the fracture fragments that are then fixed with pins connected to an external fixator [21]. With the MIROS four pins are used, the ends of which are blocked in a clip placed externally on the skin. The rationale of these techniques is to stabilise the fracture fragments by shifting the site of fixation from the cancellous bone of the proximal humerus to the stronger

Table 4 Complications in the two groups of patients

	TPP (27)	<i>p</i> values	MIROS (31)
Overall complications	7 (26.92%)	0.008	3 (10.7%)
Pin tract infection	4 (15.38%)	>0.001	0
Pin mobilisation	7 (26.9%)	>0.001	0
Pin displacement	0	0.8	1 (3.57%)
Deep infection	1 (3.84%)	0.6	0
Avascular necrosis	2 (7.69%)	0.8	2 (7.1%)

bone of the lateral cortex of the humeral diaphysis. They also allow passive shoulder motion to be started a few days after surgery. However, only the humerus block and MIROS are minimally invasive techniques that can be carried out under brachial plexus block. Compared to the humerus block, the MIROS has the advantage that four pins, instead of two, can be anchored to the locking device. The four pins can provide better fracture fixation, with no need for percutaneous screws to fix tuberosities not stabilised by the pins. Furthermore, the external placement of the locking device allows the instrumentation to be removed when the fracture has healed with no need of a further operation, which can be problematical in older patients in very poor general condition (ASA PS four).

In patients treated with the MIROS the mean fluoroscopy time was significantly longer than in those of the TPP group. However, the longer X-ray exposure was justified by the clinical results, which were significantly better in the former group at the latest follow-up. The mean CS ranged from 53.5 points at the six-month follow-up to 60 points at the latest evaluation, i.e. significantly higher figures than those obtained in the TPP group. One explanation for the differences between our two groups may be the more stable fixation of the fracture fragments in the MIROS patients, which allowed the rehabilitation programme to be started earlier. Another reason may be related to the complications, which were similar to those in the TPP group, but occurred at a significantly lower rate, except for avascular necrosis.

In both groups the clinical results were better in patients with three-part fractures compared to those with four-part injuries, which is understandable considering the greater difficulty in obtaining a satisfactory reduction in four-part lesions. Based on this finding, we believe that methods of percutaneous pinning should be avoided in young or middle-aged patients in the absence of comorbidities that contraindicate ORIF. In older patients in poor general condition, the percutaneous procedure with MIROS can even be performed with the only aim of pain relief. However, the main goal of the procedure is not to jeopardise the already critical health status of individuals even with a long life expectancy, in whom a satisfactory functional outcome is of primary importance for performing the activities of daily living. Furthermore, it can also be indicated for elderly patients in satisfactory general health in whom there is less need of anatomical fracture reduction and excellent functional result than in younger patients.

The reported incidence of avascular necrosis of the humeral head after traditional pinning ranges from 4% [17] to 14% [20]. In our cohorts, it was 7.7% in patients undergoing TPP and 7.1% in those treated with the MIROS. This indicates that the occurrence of avascular necrosis is related to the type of fracture and the extent of compromise of the arterial supply to the humeral head rather than the stability

of fixation of the fracture fragments. The four patients with avascular necrosis in our cohorts had the lowest CS and SSV scores at the latest evaluations. However, only in one was there a clear-cut indication for hemiarthroplasty, which could not be performed due to the poor general condition.

In conclusion, our study shows that, although TPP can be a valid treatment for three- or four-part fractures, the MIROS gives better results. However, both types of treatment imply closed reduction of the fracture, which can be a very demanding procedure that may fail to provide a satisfactory reduction, particularly in four-part injuries. Therefore, not only in the young, but also in the middle-aged patient with no general comorbidities, ORIF should generally be preferred to percutaneous pinning.

Conflict of interest The authors declare that they have no conflict of interest.

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