

SINGLE OR DOUBLE PLATING FOR NONUNION OF THE CLAVICLE

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Between January 1982 and January 1999, 684 patients presented with a fracture of the clavicle to the accident and emergency departments of the Tamside and Bury District General Hospitals. Twenty patients (3%) subsequently developed symptomatic nonunion of the clavicle. The original injury resulted from a road traffic accident in 13 patients, from a fall on an outstretched hand in five patients, and two patients had sports related injuries. Mean age of the patients was 39 years (range, 17 to 76 years). Mean time from injury to surgery was 2.5 years (range, 6 months to 8 years). Fifteen patients underwent open reduction and internal fixation of the nonunion of the clavicle with a single plate (DCP or AO plate) and in the remaining five patients two plates were used. The clavicle went on to unite both clinically and radiographically in all patients. Mean time for clinical recovery of symptoms was 4 weeks (range, 3 to 15 weeks) and mean time for radiological union was 17 weeks (range, 15 to 35 weeks). The Constant score component for pain rose from a preoperative score of 0.71 to 13.8 ± 3.5 ($p < 0.0001$, paired t-test). There was significant improvement for the level of activity of daily living from a preoperative score of 2.95 ± 1.63 to 19.0 ± 3.9 . ($p < 0.0001$, paired t-test). The Imatani score for shoulder function rose from a preoperative score of 56.75 ± 5.9 , to a postoperative score of 98.39 ± 4.0 . No complications related to surgery were noted in the immediate postoperative period. Three patients required removal of the metal work. After removal of the plates there were no refractures of the clavicle. In conclusion, single or double plating of the clavicle is an effective technique in dealing with nonunions of both middle and distal thirds of the clavicle.

Keywords : clavicle ; nonunion ; plate fixation.

Mots-clés : clavicule ; pseudarthrose ; plaque vissée.

INTRODUCTION

The clavicle is the most commonly fractured bone in children (26) and accounts for about 50% of fractures of the shoulder girdle in adults (22). Complications and morbidity associated with these fractures are rare in children (8). Displaced fractures of the clavicle not uncommonly lead to nonunion causing pain and dysfunction in adults (17). Once nonunion of the clavicle is established and is symptomatic surgical intervention is often needed. Surgery has been associated with increased failure rate as compared to the conservative treatment in the management of acute clavicle fractures (23). Various options have been tried. Operative techniques reported in literature consisted of coracoclavicular screws (1), intramedullary fixation with long pins and screws (2), open reduction and internal fixation with plates (10), external fixation (25), lag screws fixation (4) and bone grafting (6, 11, 22, 27). The fact that the anatomy of the clavicle is complex, and no single fixation method may be suitable for both middle and distal third fractures, has made the choice of implant more difficult. We report a series of 20 patients treated with plating of the clavicle using an AO reconstruction plate or a DCP plate in order to achieve rigid internal fixation for immediate mobilization of the extremity. Five patients who had clavicle nonunion required fixation with two plates to secure bone

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grafts and provide added stability. All fractures healed uneventfully with no surgical complications with full recovery of patients' symptoms of pain and disability due to nonunion.

PATIENTS AND METHODS

Between 1982 to 1999, 684 patients were referred with clavicle fractures to Tameside and Bury district General Hospitals. Twenty patients (3%) subsequently developed symptomatic nonunion of the clavicle. The mechanism of injury was a road traffic accident in 13 patients, a fall on an outstretched hand in five patients, and two patients had sports related injuries. Three patients also had associated rib fractures. There were 13 men and seven women. Fifteen patients had open reduction and internal fixation with either a single DCP or an AO reconstruction plate. Five patients underwent open reduction and fixation with two plates (combination of AO reconstruction, or semitubular) of their clavicle fractures. This series included patients in whom clavicle fractures failed to unite at the end of four months from the time of injury and were declared as nonunions of the clavicle. Data were collected taking into consideration age, sex, hand dominance, mechanics of injury, associated injuries, initial management, and major complaints by the patients after established nonunion. All 20 patients were experiencing either considerable pain or significant disability in the use of the upper limb and were not able to go back to work. The age range for the patients was from 24 to 74 years. Mean time from injury to surgery was 20 months (range, 4 months to 84 months). Nineteen patients had middle-third clavicle fractures and one patient had a lateral-third clavicle fracture. The radiological appearance was consistent with atrophic nonunions in 13 cases, and hypertrophic nonunions in seven cases. Initial management of all fractures consisted of a period of immobilization in a collar. Physiotherapy was started as early as possible once pain allowed the use of the upper limb. Conservative treatment was abandoned with persistence of the patient's symptoms and no radiological sign of healing at the fracture site at a minimum time of four months.

Surgical Technique

The patients were operated in beach chair position. A suprascapular incision was performed over the clavicle in all cases ; it was curved to accommodate the clavicle

shape. No effort was made to identify the supraclavicular nerves. The skin flaps were raised along with the subcutaneous tissue and minimal muscle attachments were peeled along with the periosteum to expose the superior surface. The nonunion site was exposed, taking care with respect to the surrounding tissues and protecting them with adequate retractors. The nonunion was curetted and by reducing the two ununited ends of the bone, the size of the graft was estimated. The bone grafts were taken from the iliac crest and put into the gap, with consideration for the length of the clavicle to be restored. A single plate was used when a 7-hole plate conformed well to the curvature of the clavicle. In case of double plating, the superior plate was placed first and an AO reconstruction plate with a minimum of 6 holes was chosen. Further bone grafts were used if necessary, and an anterior plate (AO reconstruction plate, or semitubular) was placed securing the graft in good position. Screw positions and lengths were checked under image-intensifier. Wounds were closed with a suction drain. Postoperatively, the limb was immobilized in a broad arm sling until the wound healed.

Postoperative rehabilitation

Patients were allowed to use the arm out of the sling after two weeks under the supervision of the physiotherapist. Gentle exercises were started at three weeks after surgery. Most of the patients were able to use the arm for above-shoulder activities three weeks later, and full exercises were started about six weeks from the time of surgery.

RESULTS

The patients were reviewed at two weeks and then monthly until union was established. All the 20 patients in our series had good postoperative recovery. The initial symptom of pain associated with nonunion disappeared within six weeks. Radiological union was established at a minimum of four months and maximum of six months, although there was difficulty in establishing the early callus formation owing to the position of plates. Preoperatively many patients had a marked shortening of their shoulder girdle as a result of nonunion. All patients in this study had overlapping of the fracture fragments of at least 1 cm (range 1 to 2.9 cms) on the cephalic tilt radiographic view.



Fig. 1. — a) Preoperative xray of patient with > 2 cm displacement of the fracture of the clavicle- a major predictor of nonunion ; b) xray of the clavicle fixed with two plates.

Most patients had forward and downward drooping of the injured shoulder compared with the uninjured side before the operation. Several patients described an unpleasant sensation of the fracture fragments moving before surgery. Surgery cured the reported drooping in all patients.

All patients were given a questionnaire incorporating the Constant scoring (7) to assess the shoulder girdle function before surgery was contemplated ; however not all components of the Constant score were possible to retrieve retrospectively. This score is a simple, well- recognized 100-point score, designed to give a reliable indication of shoulder function. It assesses pain (15), activities of daily living (20), range of movement (40) and power (25). The Constant score of the injured shoulder was compared with the uninjured shoulder at the most recent follow-up. The Imatani score (13) that allows retrospective assessment was also used to compare the difference in functional status of patients, preoperatively and postoperatively. There was significant improvement in the preoperative pain score of 0.71 ± 1.75 to 13.8 ± 3.5 ($p < 0.0001$, paired t-test). Before surgery, 17 patients with clavicle nonunion were either not able to resume routine work or household activities. All patients returned to routine activity four months from the time of operation.

There was significant improvement in the preoperative level of activities of daily living from 2.95 ± 1.63 to 19.0 ± 3.9 ($p < 0.0001$, paired t-test). As most patients had symptoms for a considerable time before operation, they could remember the status of the function of their upper limbs and the degree of discomfort. The mean preoperative Imatani score for the injured extremity was 56.75 ± 5.9 , and it rose to 92.38 ± 4.53 . This difference was highly statistically significant with $p < 0.0001$ (Wilcoxon Rank test).

The Constant score was found insufficient to discuss the cosmetic results of the surgical procedure and local palpability of the plates. All our patients felt that the plates and screws were palpable, but none of them were concerned about this to a great extent. We have removed the plates so far in one man and two women, and no complications have been reported so far after the removal of plate six months from the time of surgery.

DISCUSSION

The incidence of nonunion of the clavicle has been reported to be between 0.4 to 4.0% (17). In a study of 52 patients with displaced fractures of the middle third of the clavicle, the nonunion rate has been reported as high as 15% (12). The age of the patient, an initial displacement of the fracture



Fig. 2. — Middle-third fracture fixed with two plates

fragments, overriding of the broken fragments, refracture, and other associated injuries are important factors leading to a higher nonunion rate after clavicle fractures (18, 22). Nonunion is higher in the middle-third fractures of the clavicle followed by lateral-third fractures (17). Earlier studies showed higher rates of nonunion in patients who had undergone primary fixation of the fractures. Neer reported nonunion rates of 0.1% after conservative treatment and 4.4% after operative treatment (18). Rowe (23) reported nonunion rates of 0.8% after conservative treatment and 3.7% after operative treatment. Schwartz and Leixnering (24) reported a nonunion rate of 13% in patients with primary open reduction of clavicle fractures and Poigenfürst *et al.* (21) reported a complication rate of 10%, with four nonunions in 60 fresh clavicle fractures treated with internal plate fixation. In a recent study of acutely displaced clavicle fractures that were treated with internal fixation, 24% of patients suffered from complications that included a significantly high rate of infection of 7.5% (3). Poor internal fixation, rather than the surgery itself, may play the primary role in the increased incidence of nonunion in clavicle fractures treated with primary surgery.

Nonunion is characterized by failure to show clinical or radiographic progression of healing at four to six months (17, 19, 22). Nonunion may be either atrophic or hypertrophic, the former being a more common pattern than the latter. Nonunion may lead to pain, and difficulty in the use of upper

limb leading to loss of occupation. Pain in nonunion may be caused by painful nonunion, hypertrophic callus pressing on the surrounding structures with neurovascular compression or shortening and dysfunction of the shoulder girdle (14). The incidence of painful nonunion has been reported as high as 75% in one study (22).

A careful history and physical examination is essential to exclude soft-tissue and bony abnormalities around the shoulder, including posttraumatic arthritis of either the sternoclavicular or acromioclavicular joints, which can mimic the symptoms of a nonunion. Most symptomatic nonunions are the result of significant primary trauma rather than a simple break. It is not uncommon to miss the associated primary injuries. In this study of 20 patients who developed nonunion of the clavicle, five patients had associated injuries. These included multiple rib fractures in three and two patients had features of thoracic outlet syndrome. In this study, the significant initial fracture displacement appeared to be the critical factor associated with nonunion. There were no follow-up data available for the patients who developed nonunion but were asymptomatic.

Nonoperative methods to obtain union have been reported, particularly the use of electrical stimulation. However, there have been only a few documented cases of healing of clavicle nonunion by pulsed electromagnetic fields, and most authors share the view that there is little role for electrical stimulation in the treatment of this complication (6).

There are short reports with fixation of acute fractures with a special clavicle plate (11), reabsorbable implant (15), coracoclavicular screw fixation (1) and even excision of the distal fragment (16). The contour of the clavicle with muscular forces acting on the fracture fragments puts any device under great tension. The clavicle exhibits considerable movements in three planes, and the pull of strong muscular forces in opposite directions. As some of the methods like intramedullary fixation control rotation poorly, neither suture nor screw fixation is secure enough to be reliable without additional protection or prolonged immobilization postoperatively. It is not uncommon to

find the wires migrating, screws bending and breakage leading to disruption of the plates. One-third tubular AO plates are especially prone to failure and are not suitable for the fixation of clavicle (21). Some authors have recommended intramedullary fixation as treatment of choice for lateral-third fractures (2). In 1991, Rockwood *et al.* described a series of 21 patients with nonunion of the clavicle who were treated successfully with intramedullary modified Hagie pins. Compared with plates and screws, intramedullary fixation has several advantages. The intramedullary pin can be inserted through a cosmetically acceptable incision and requires less dissection; it can be removed through a small incision under local anesthesia. Intramedullary devices however are difficult to insert, in particular with atrophic bone ends of the nonunited clavicle.

Once surgery is indicated, open reduction and internal fixation with plate fixation is the most commonly used method described in the literature with high success rates (3, 4, 9, 10, 27). Most surgeons have used LC-DCP, reconstruction AO plates and one-third tubular plates with or without bone grafting. Jupiter and Lefort (14) reported on 23 cases of nonunion of clavicles with an overall success rate of 89%. However 97.3% of those treated with grafting and DCP achieved union. In another study of 16 patients with clavicle nonunions, 15 patients healed eventually (10). Bradbury *et al.* (4) compared the results of a reconstruction plate versus a dynamic compression plate. In the above study, 15 patients were treated with DCP plates and 17 had reconstruction plates. One patient who had a reconstruction plate to fix the clavicle had failure due to infection. However, the author recommended the use of reconstruction plates because of the easy adaptability of the plate. In none of the above studies were high infection rates reported as compared to the high infection rates reported in the acutely fixed clavicle fractures (3). This may be attributed to better soft tissue healing in delayed fixation of the clavicle. The internal fixation by providing rigid fixation allows early mobilization of the limb. Plate fixation requires implant removal and thus another operation in 10-30% of the patients treated with this method (5).

Open reduction and internal fixation with plate and screws provides consistent results in the management for clavicle nonunion. Bone grafting should be an integral part of this procedure, as considerable shortening of bone ends is noted in most cases of atrophic nonunions. The characteristic deformity in clavicle fractures is that of an apex superiorly of the distal fragment pulled inferiorly by the weight of the upper limb (14). This retrospective study consisted of 20 patients who had fixation of the clavicle nonunion with plates and screws, and in five of the patients the clavicle nonunions were internally fixed using two plates. Whenever a plate is placed superiorly on the bone it acts as a tension band device. At least three screws on either side of the nonunion are required to provide sufficient stability. Hence where a single plate is used, a 7-hole plate is the minimum length of implant to be chosen. Where this is not possible and excessive bending of the plate is required to match the contour of the clavicle, the use of another plate should be considered. The use of two plates provides added stability and is of interest to fix an overlay or intercalary bone graft.

In conclusion, open reduction and internal fixation with single or double plating of the clavicle combined with bone grafting provides solid fixation in most cases of nonunion. However all patients need to be counseled about the possible complications and the need for a second operation for removal of the implant.

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SAMENVATTING

S. SADIQ, M. WASEEM, B. PERAVALLI, J. DOYLE, T. DUNNINGHAM, B. N. M. MUDDU. *Enkelvoudige of dubbele plaatfixatie voor pseudarthrosis van de clavícula.*

Tussen Januari 1982 en Januari 1999 werden op de spoedgevallendienst van de "Tamside and Bury district General Hospitals" 684 sleutelbeenbreuken behandeld, waarvan 20 (3%) leidden naar pseudarthrosis. De oorzaak van de breuk in deze niet-helende gevallen was een verkeersongeval in 13, een val op de uitgestrekte hand in 5, en een sportongeval in 2 patiënten. De gemiddelde leeftijd van de slachtoffers was 39 jaar, gaande van 17 tot 76 jaar. Het gemiddeld interval tussen ongeluk en heelkundige behandeling was 2,5 jaar, gaande van 6 maanden tot 8 jaar. Bij 15 patiënten werd geopteerd voor open reductie en fixatie met één plaat (DCP of AO) ; bij de overige 5 patiënten werd een dubbele plaatfixatie verkozen. Klinische en radiologische beenderige overbrugging werd bekomen in alle 20 gevallen. Het klinisch herstel was gemiddeld bereikt in 4 weken (van 3 tot 15 weken). Radiografische overbrugging duurde gemiddeld 17 weken (15 tot 35 weken). De Pijn index in de Constant score, steeg van 0,71 preoperatief tot 13,8 ± 3,5 (p < 0,0001, paired t-test). De Functionele index steeg van 2,95 ± 1,63 preoperatief tot 19,0 ± 3,9 (p < 0,0001, paired t-test). De schouderfunctie score volgens Imatani steeg van 56,75 ± 5,9 preoperatief tot 98,39 ± 4,0 postoperatief. Er traden geen chirurgische complicaties op in de onmiddellijke postoperatieve periode. Het materiaal werd verwijderd bij drie patiënten, zonder dat er een refractuur optrad. Als besluit : enkelvoudige, zowel als dubbele plaatfixatie is afdoende

in de behandeling van pseudarthrosis van zowel het middelste, als het buitenste derde van de clavicula.

RÉSUMÉ

S. SADIQ, M. WASEEM, B. PERAVALLI, J. DOYLE, T. DUNNINGHAM, B. N. M. MUDDU. Ostéosynthèse des pseudarthroses de la clavicule par une ou deux plaques vissées.

Entre janvier 1982 et janvier 1999, 684 patients se sont présentés avec une fracture de la clavicule aux urgences des hôpitaux régionaux de Tamside et Bury. Vingt d'entre eux (2,9%) ont évolué vers une pseudarthrose symptomatique. Au départ, la fracture résultait d'un accident de la voie publique chez 13 patients, d'une chute sur le membre supérieur en extension chez 5 autres ; deux des lésions étaient d'origine sportive. L'âge moyen des patients était de 39 ans (extrêmes : 17 et 76 ans). L'intervalle entre la fracture et le traitement chirurgical était en moyenne de 2,5 ans (extrêmes : 6 mois et 8 ans). Quinze

patients ont subi une réduction à foyer ouvert suivie d'ostéosynthèse au moyen d'une plaque vissée unique (DCP ou AO) ; deux plaques (une DCP et une AO) ont été utilisées chez les 5 autres. La consolidation clinique et radiologique a été obtenue chez les 20 patients. Sur le plan clinique, les plaintes avaient disparu en moyenne après 4 semaines (extrêmes : 3 et 15 semaines), le délai de consolidation radiologique moyen a été de 17 semaines (extrêmes : 15 et 35 semaines). La cotation de la douleur dans l'échelle de Constant est passée de 0,71 en préopératoire à $13,80 \pm 3,5$ ($p < 0,001$). La cotation du niveau d'activité est passée de $2,95 \pm 1,63$ en préopératoire à $19,0 \pm 3,9$ ($p < 0,0001$). Le score d'Imatani pour la fonction de l'épaule est passé de $56,75 \pm 5,9$ en préopératoire à $98,39 \pm 4,0$. Aucune complication en rapport avec la chirurgie n'a été notée dans le post-opératoire immédiat. Le matériel d'ostéosynthèse a dû être enlevé chez 3 patients ; aucune refracture n'a été notée par la suite. En conclusion, l'ostéosynthèse par plaque simple ou double est une technique efficace dans le traitement des pseudarthroses du tiers moyen et du tiers externe de la clavicule.