OPERATIVE TREATMENT OF HUMERAL SHAFT FRACTURES THE LEUVEN EXPERIENCE

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For many years, plating has proved to be a reliable method for the fixation of fractures of the humeral shaft. In the early nineties however, intramedullary devices became increasingly popular for fractures of the humeral shaft. This was based on a global tendency towards minimally invasive surgery, and the attractiveness of the relatively simple procedure and potentially lower complication rate of intramedullary nailing, which had proved to be successful in osteosynthesis of the lower limb, However, until now there is no consensus in the literature as to which device is preferable for different indications.
We reviewed 161 patients, operatively treated for a fracture of the humeral shaft in our department between 1986 and 1999. Our experience shows in most indications a higher union rate, better functional results and a lower reoperation rate after plate and screw fixation. In addition, even though plating requires a more technically demanding procedure, in experienced hands, it gave rise to fewer iatrogenic fractures, and fewer persisting pain problems. We recommend the use of plate and screws as primary treatment in all operative indications, except for pathological fractures, very obese patients, and open fractures.

Keywords : humerus ; diaphyseal fracture ; internal fixation.
Mots-clés : humérus ; fracture diaphysaire ; ostéosynthèse.

INTRODUCTION

Although nonoperative treatment may be successfully used for the majority of fractures of the humeral shaft, operative intervention is indicated in several situations. For many years, plate and screw osteosynthesis has proved to be a reliable method for the operative fixation of fractures of the humeral shaft. In the early Nineties however, intramedullary devices became more and more popular, based on a global tendency towards minimally invasive surgery, and the attractiveness of the relatively simple procedure and potentially lower complication rate of intramedullary nailing, which had proved to be successful in osteosynthesis of the lower limb. Nevertheless, the latter has also been criticized by several authors, and up to now, there is still no consensus about the preferable device in each situation. Based on our own experience and a careful literature review, we will give our opinion on operative indications and the prefered device in each of these indications.

MATERIAL AND METHODS

Between 1986 and 1999, 232 fractures of the humeral shaft were treated operatively in our department. The patients ranged in age from eight to 97 years, with an average of 46.2 years. We studied 122 men and 110 women. For 161 patients, sufficient follow-up data were available in our department. Of these, 80 had their fracture treated with plate and screw fixation and 81 were treated with an intramedullary device. Respectively one and two of these were temporarily treated by

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Table I. — AO-fracture classification for our population

AO-classification	Global (n = 161)	Plated (n = 80)	Nailed (n = 81)
Type A : simple (non comminuted) fractures	91	40 (50%)	51 (63%)
A1 : spiral fracture	36	15	21
A2 : oblique fracture	7	2	5
A3 : transverse fracture	48	23	25
Type B : fractures having a butterfly fragment	46	26 (32.5%)	20 (24.7%)
B1 : spiral fracture	17	7	10
B2 : bending wedge fracture	22	13	9
B3 : fracture with more than one fragment	7	6	1
Type C : comminuted fractures	24	14 (17.5%)	10 (12.3%)
C1 : double spiral fracture	12	7	5
C2 : segmental fracture	5	1	4
C3 : complex fractures	7	6	1

Table II. — Indications for operative treatment

Indications	Overall		Plated		Nailed	
	n	*%*	*n*	*%*	*n*	*%*
Fracture type	57	*35.4%*	23	*28.75%*	34	*42%*
Spiral fracture	*38*		*12*	*15%*	*26*	*32.1%*
Complex fracture	*12*		*9*	*11.25%*	*3*	*3.7%*
Segmental fracture	*3*		*1*	*1.25%*	*2*	*2.5%*
Transverse fracture	*4*		*1*	*1.25%*	*3*	*3.7%*
Polytrauma	45	*27.9%*	26	*32.5%*	19	*23.5%*
Failed conservative treatment	16	*9.9%*	13	*16.25%*	3	*3.7%*
Unsatisfactory alignment	*12*		*9*		*3*	
Nonunion	*4*		*4*			
Radial Nerve palsy	15	*9.3%*	10	*12.5%*	5	*6.2%*
Full	*9*		*6*		*3*	
Partial	*3*		*2*		*1*	
Progressive	*3*		*2*		*1*	
Open fracture	8	*5.0%*	4	*5%*	4	*4.9%*
Floating Elbow	2	*1.2%*	1	*1.25%*	1	*1.2%*
Wheelchair patient	1	*0.6%*			1	*1.2%*
Obesity	1	*0.6%*			1	*1.2%*
Amputation	1	*0.6%*	1	*1.25%*		
Other	15	*9.3%*	2	*2.5%*	13	*14%*
Total	*161*	*100%*	80	*100*	81	*100%*

external fixation for a maximum of two weeks (all open fractures). The choice of the fixation device was determined by general considerations in the literature at the time of intervention and finally by the opinion of the individual surgeon. Overall the procedures were performed by or under direct supervision of an experienced member of staff.

We used Dynamic Compression Plates (DCP), Low Contact Dynamic Compression Plates, and Waldemar Link plates, all but three broad plates, applied using an

Fig. 1. — Retrograde locked intramedullary nail

Fig. 2. — Plate and screw osteosynthesis

Table III. — Time to union

Time to union	Global		Plate		Nail	
	n	%	*n*	%	*n*	%
Union	131	81.4%	74	92.5%	57	70.4%
Delayed Union	18	11.2%	6	7.5%	12	14.8%
Nonunion	12	7.4%	–		12	14.8%

anterolateral approach in 60% of the cases and using a posterior approach in 40%. As an intramedullary device, we used Unreamed Humeral Nails® (Mathys, Switzerland) and Russell-Taylor® (Smith and Nephew, USA) nails. Eight nails were inserted in an antegrade fashion and 72 in a retrograde fashion. Fractures were classified according to the AO classification (table I). Operative indications were polytrauma, failed conservative treatment, radial nerve palsy, open fracture, floating elbow, wheelchair patient, extreme obesity, amputation, and unstable fracture type (table II). Union was defined as fracture healing within 6 months after treatment. Healing between six months and one year was considered to be a delayed union. The fractures not healed within one year and those requiring re-osteosynthesis were classified as nonunions. The functional results were qualified as excellent, good, fair, or poor. An excellent functional result was considered to be achieved when functional recovery was complete. Suboptimal functional recovery, without consequences for work and everyday activity was qualified as a good functional result. Disturbance of daily activity and work due to functional loss was qualified as a fair functional result. When pre injury work and/or some of the daily activities had to be abandoned owing to functional loss, we considered this as a poor functional result. Results were statistically evaluated with Fisher's Exact test.

Table IV. — Results of reoperation after nonunion

Reoperation	Union		Delayed union		Nonunion	
	n	%	*n*	%	*n*	%
Plate (N = 7)	7	100%	-	-	-	-
Nail (N = 3)	1	33.3%	1	33.3%	1	33.3%
Compression screw (N = 1)	1	100%				
Cancellous graft (N = 1)	1	100%	-		-	
Global (N = 12)	10	83.3%	1	8.3%%	1	8.3%

Table V. — Functional recovery

Functional recovery	Global		Plated		Nailed	
	n	%	n	%	n	%
Excellent	118	73.3%	62	77.5%	56	69.1%
Good	35	21.7%	14	17.5%	21	25.9%
Fair	4	2.5%	2	2.5%	2	2.5%
Poor	4	2.5%	2	2.5%	2	2.5%

RESULTS

Union was achieved in 81.4% of all included fractures, delayed union in 11.2% and nonunion in another 7.4%. Union rate was significantly higher in the plated group than in the nailed group ; 92.5% vs 70.4% (table III ; $p < 0.001$). Nonunion was significantly higher in the nailed group (14.8% vs 0%). Among these, there were three hardware failures : two migrations of a distal locking screw and one proximal migration of the nail. Reoperation was performed in all nonunions using plate and screws (N = 7), UHN (N = 3), cancellous bone graft (N = 1) or compression screws (N = 1) (table IV). There was no significant difference in functional results between the plated and the nailed group (table V). Overall we achieved 73.3% excellent, 21.7% good, 2.5% fair and only 2.5% poor functional results. Fifteen patients presented with a preoperative radial nerve palsy associated with their fractures. Ten (66.7%) of these fractures were treated with a plate, permitting radial nerve exploration in one single approach. Seven radial nerves showed no lesion at exploration, one presented with a contusion and another one with an elongation. Only one radial nerve was found entrapped in the fracture requiring neurolysis. The remaining five cases were nailed, in three of which an exploration of the radial nerve was performed by a second approach. In these procedures, the radial nerve was found to be intact once and elongated in two cases. In all but one case (93.3%), we finally achieved a full recovery of the radial nerve after three to 16 months.

Postoperatively, eight patients developed radial nerve palsy ; four after nailing and four after plate and screws (table VI). In three of four plating procedures the radial nerve was visualised intraoperatively to be intact. One neurolysis for entrapment of the radial nerve in the fracture was performed, during a second intervention for nonunion after nailing. Radial nerve recovery was full in all but one case, after two up to 13 months.

We noted four iatrogenic fractures, all at the time of insertion of a nail. Three of these required conversion to plate and screws. Nine patients, all treated with a retrograde nail, suffered persisting functional restriction or pain in the elbow, until removal of the device. Two of these required arthrolysis. Two antegrade nailed fractures gave rise to a persisting pain problem of the shoulder. Hardware failure occurred in two plated fractures, consisting twice of a migration of screws. One plate was replaced by another plate. In the second case the screws were reinserted in cement in the osteoporotic bone. Two retrograde nails presented with prox-

Table VI. — Complications

Complication	Plated n	%	Nailed n	%	Overall n	%
Radial nerve palsy	4	5%	4	4.9%	8	5%
Recovery	4		3		7	
Iatrogenic fracture	–	–	4	4.9%	4	2.5%
Pain/Funct restriction	–	–	11	13.6%	11	6.8%
shoulder			2		2	
elbow			9		9	
Hardware failure	2	2.5%	4	4.9%	6	3.7%
Proximal migration	–		2			
Migration screws	2		2			
Compartment syndrome	–	–	1	1.2%	1	0.6%

imal migration of the nail. One nail was removed after one year for that reason and the other was replaced after one month by a another retrograde nail. Two antegrade nails presented with migration of distal locking screws and were replaced by a nail and a plate respectively. One patient developed a compartment syndrome after his fracture was nailed, with a radial nerve palsy from compression. Therefore a fasciotomy was performed, and eventually full radial nerve recovery and an excellent functional result was achieved. No infections occurred in our series. Overall, a reoperation was performed in 21 cases ; three after plating (3.75%) and 18 (22.2%) after nailing, which is a significant difference ($p < 0.001$).

DISCUSSION

Any discussion concerning surgical treatment of humeral shaft fractures must first consider the excellent results that can be achieved with nonoperative care of this fracture, with reported union rates of more then 90%, and 100% full functional recovery (32, 39, 40). However, there still remain certain fracture types and associated injuries which require an operative management. The operative indications in our series are summarized in table II. Evidence for these can be found in the literature.

In open humeral fractures, fracture stabilization after soft-tissue and osseous debridement has been reported to reduce the incidence of infection. In fractures with associated vascular injury operative fixation is indicated after vascular repair, to prevent repair damage by fracture motion (12, 13, 21, 23, 24, 34, 35, 36, 39, 40). In patients with a floating elbow or shoulder, internal fixation of the long bones can be followed by early exercises of adjacent joints, reducing the risk for stiffness, and decreasing the potential for nonunion or malunion (4, 10, 13, 16, 20, 24, 29, 30, 35, 40). Conservative treatment of segmental fractures, is associated with increased risk of non-union (4, 9, 10, 23, 40).

Each pathological fracture should be internally stabilized to maximize the patient's pain relief and upper extremity function and to ease nursing care (9, 10, 16, 21, 23, 30, 35, 37, 40). The patient with polytrauma is often unable to remain in the semi sitting position necessary to maintain fracture reduction, and operative stabilization of the humerus may be necessary to facilitate nursing and to maximize the recovery and rehabilitation potential of this patient (2, 13, 21, 23, 24, 30, 35, 36, 40).

Nonunion and pseudarthrosis are complex problems demanding operative care, including realignment of the mechanical axis, debridement of infected tissue, pseudarthrosis stabilization, cancellous bone grafting in case of atrophic nonunion or bone loss, and early range of motion exercises of the adjacent joints (13, 35, 36, 40). The management of humeral (mid-) shaft fractures with associated radial nerve injuries has been the subject of some controversy. When nerve exploration is performed,

there is agreement about stabilizing the fracture operatively at the same time. However, there is no consensus on the exact indications for nerve exploration. Recommendations classically have been that closed fractures associated with immediate (prereduction) palsy have to be managed nonoperatively, because spontaneous recovery after such injuries has been reported to occur in 73%-90% of patients (6, 17, 24). For radial nerve injuries in combination with open fractures or associated with intact nerves before reduction, exploration has been recommended (1, 2, 3, 13, 16, 24, 35, 37, 40). An additional indication for nerve exploration would be those patients with electrophysiologic evidence of failure of demonstrable reinnervation patterns 3 months after injury (17, 27, 40). These concepts however have been challenged by others. They argue that the poor result of late exploration with or without nerve repair (17), the higher incidence of radial nerve entrapment between fractures in the middistal 1/3 fractures (1, 16, 17), and a more technically demanding surgical procedure that is necessary when the nerve is encased in callus, justify operative treatment after primary nerve injury in some cases. Furthermore, they report that "the early exploration can provide the surgeon and the patient with a full understanding of the status of the radial nerve and the outcome after exploration" (23). Stable plate fixation at the same time may also protect the nerve from being entrapped in nearby exuberant callus formation (27).

The inability to obtain or maintain an adequate closed reduction is a relative operative indication (23, 40). In the humeral shaft, one can accept up to 3 cm shortening, 20° angulation in the AP-plane and 30° in the mediolateral plane (3, 19, 37, 40). Malrotation is usually well tolerated owing to ipsilateral compensatory shoulder motion, if the patient has a normal shoulder. Humeral fractures in obese patients and women with pendulous breasts are at increased risk of varus angulation (40). Fractures of the humeral shaft associated with intra-articular fracture extension require operative treatment, to prevent loss of adjacent joint function (23, 33, 40). Fractures with associated burns may preclude closed treatment and thus request an operative approach (10, 23). Rommens *et al.* added transverse fractures and long spiral fractures to the previous list of indications. Furthermore they argued ; "There is a growing tendency for operative treatment. For patients and surgeons, plaster cast treatment or immobilization of an upper extremity against the thoracic wall are not as popular as they were one generation ago" (30). Nast-Kolb *et al* reported that "besides these, there are cases of individual, professional and social indications" (24). This agrees in some way with Zuckerman/Koval and Linn, recommending that uncooperative and unreliable patients should not be treated by functional bracing (21, 40).

The choice of the fixation device in this retrospective study was determined by general considerations in the literature at the time of intervention and finally by the opinion of the individual surgeon. For many years plates had proved to be a very reliable fixation method in our department as well as in the published experience of other authors. This was supported by biomechanical studies reporting plate fixation to be a potential good solution, with superior bending stiffness and rigidity compared to intramedullary nailing and good torsional stiffness (7, 34, 38). In the early Nineties though, based on a global tendency towards minimally invasive surgery and the attractiveness of the relatively simple procedure and potentially lower complication rate of intramedullary nailing, which had proved to be successful in osteosynthesis of the lower limb, plate and screws were partially abandoned in favor of intramedullary devices for fractures of the humeral shaft in our department too. We preferred locked humeral nails to bundle nailing in view of the instability of the latter technique, although several authors have reported satisfying results after bundle nailing with Hackethal nails (11, 15, 25, 26, 28). The final outcome, however, did not convince us of the superiority of intramedullary nailing. For this reason, we gradually performed more plating procedures from 1995 onwards. Overall we noted in our series that a significantly higher percentage of plates was used in some of the more difficult circumstances : polytrauma, radial nerve palsy and unsatisfactory alignment (added percentages : 61% vs 34% ($p = 0.001$)). Despite this, the global union rate was

significantly higher in the plated group than in the nailed group. There was no significant difference in functional result between the plated and the nailed group, although plates scored slightly better. Complications occurred in both plated and nailed groups, but a reoperation was required significantly more often in the nailed group ; 22.2% vs 3.75%. This experience with union rate, functional recovery and complication rates with both nails and plates was confirmed by the randomised prospective trial of McCormack *et al*. published in 2000 (22). Therefore, plate and screws are our treatment of choice in most operative indications.

For unstable fracture types and after failed previous conservative/operative treatment, plating offers direct visualization and if necessary the possibility to take surgical actions such as open reposition, radial nerve identification and protection, resection of a pseudarthrosis, and cancellous bone grafting. Furthermore deformity or bony obliteration of the canal may substantially increase the technical difficulty of nailing after failed previous treatment. The highest success rate in dealing with nonunions has been reported with compression plating with adjunctive cancellous bone (5, 8, 12, 31). Note that for some unstable fracture types, intramedullary nailing offers the advantage of giving interfragmentary compression and automatically exact anatomical alignment.

For fractures associated with vascular injury and/or radial nerve palsy, if considered to be an operative indication, plating can be performed at the same time and through the same posterior incision as required for nerve and/or vascular control and repair. In open fractures, plate fixation is preferable because of the preservation of the endosteal blood supply and the advantage of a single exposure for osteosynthesis, soft tissue debridement and inspection of the radial nerve, which is at higher risk to be injured in these usually high-energy traumas. However, open fractures with severe soft tissue damage and contamination should be stabilized temporarily using external fixation methods (21, 23).

If early mobilization with crutch walking is necessary for adequate rehabilitation in polytrauma patients, intramedullary fixation offers the advantage of acting as a load sharing implant (10, 23). In fractures with associated articular extension nailing through the involved joint is excluded whereas nailing through the intact joint often offers incomplete control of the opposed fracture fragments.

For pathological fractures of the humerus, patient comfort, self care and nursing facilities in the short term obviously are the most important considerations and the relatively simpler nailing can be preferable.

In wheelchair patients, obese, and uncooperative patients the operative management when necessary will be determined by the fracture type and other associated pathology. Some authors suggest that for osteoporotic bone, an intramedullary nail could give more stable fixation (14).

CONCLUSION

Despite the enthusiasm about intramedullary nailing of fractures of the humeral shaft in the early nineties, our experience shows in most indications a higher union rate, better functional result and lower complication and reintervention rates after plate and screw fixation. This experience has been supported by biomechanical and clinical studies. Therefore we recommend the use of plate and screws as the primary treatment for fractures of the humeral shaft in all operative indications, except for pathological fractures, very obese patients (intramedullary device + antirotation brace), and open fractures (temporary external fixation).

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SAMENVATTING

F. S. L. MEEKERS, P. L. O. BROOS. Operatieve behandeling van humerusschaft fracturen. De Leuvense ervaring.

Door de jaren heen heeft de plaat en schroef osteosynthese bewezen een betrouwbare methode te zijn voor de interne fixatie van fracturen van de humerusschaft. In het begin van de jaren negentig werden intramedullaire systemen echter geleidelijk aan populairder. Dit was gebaseerd op een globale tendens naar minimaal invasieve chirurgie enerzijds en anderzijds op de aantrekkingskracht uitgaande van een relatief eenvoudige techniek met een potentieel lage complicatie ratio welke bovendien bewezen had succesvol te zijn in de osteosynthese van het onderste lidmaat. Hoedanook, tot op heden is er geen consensus in de literatuur over welke techniek de voorkeur geniet voor de diverse operatieve indicaties.
Wij hebben 161 patienten met een fractuur van de humerusschaft nagekeken die tussen 1986 en 1999 op onze dienst operatief werden behandeld. Onze ervaring toont voor de meerderheid der indicaties een hoger helingspercentage, betere functionele resultaten en een lagere revisie graad na plaat en schroefosteosynthese. Daarenboven gaf plaat en schroef osteosynthese, hoewel in principe technisch veeleisender, in ervaren handen aanleiding tot minder iatrogene fracturen en minder persisterende pijnproblemen. Wij bevelen het gebruik van plaat en schroeven dan ook aan als primaire behandeling voor alle operatieve indicaties, behalve voor pathologische fracturen, erg obese patienten en open fracturen.

RÉSUMÉ

F. S. L. MEEKERS, P. L. O. BROOS. Traitement chirurgical des fractures de la diaphyse humérale : l'expérience louvaniste.

L'ostéosynthèse par plaque a longtemps été considérée comme un bon traitement des fractures diaphysaires de l'humérus. Cependant, il y a une dizaine d'années, l'enclouage médullaire a bénéficié d'une vogue croissante dans cette indication. C'était le résultat d'une orientation générale vers la chirurgie peu invasive, et de l'attrait d'une technique comparativement plus simple, exposant à un risque moins élevé de complications, et qui avait fait la preuve de son efficacité dans le traitement des fractures du membre inférieur. Il n'existe pourtant pas, à ce jour, dans la littérature, de consensus sur le choix de la méthode de traitement dans les différentes indications.
Les auteurs ont étudié rétrospectivement 161 patients qui ont été traités chirurgicalement dans leur service entre 1986 et 1999 pour une fracture de la diaphyse humérale. Ils ont noté dans la plupart des indications un taux de consolidation plus élevé, de meilleurs résultats fonctionnels et un taux moins élevé de réinterventions avec l'ostéosynthèse par plaque. De plus, même si cette dernière est plus exigeante sur le plan technique, elle a donné dans des mains expérimentées moins de fractures iatrogènes et moins de douleurs résiduelles. Les auteurs recommandent l'ostéosynthèse par plaque pour le traitement primaire dans tous les cas qui relèvent du traitement chirurgical, à l'exception des fractures pathologiques, des fractures ouvertes et aussi des fractures chez des patients très obèses.