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Intractable non-unions of the humeral shaft: Surgical treatment using the non-vascularized fibula technique about 10 cases in Togo

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Abstract
Introduction: The non-union is one of the most feared late complications in the treatment of fractures of the humeral shaft. The repeated failures of cures for pseudarthrosis of the humeral shaft define multi-operated pseudarthrosis also called Intractable Pseudarthrosis of Humeral Shaft (IPHS) or recalcitrant pseudarthrosis. The treatment of these IPSH requires beyond the cure of pseudarthrosis the management of bone reconstruction.
Goal: The hypothesis of this work is that the use of the non-vascularized fubular (NVF) technique with a dynamic fixation in compression by DCP plate allowed to obten a consolidation in the treatment of rebellious pseudarthrosis of the humeral shaft.
Material and Methods: It was a prospective, in single-center and single-operator study carried out at Afagnan hospital from December 2018 to December 2020 on 10 cases of IPHS. The NVF technique with dynamic and compressive fixation by DCP screwed by 4.5mm screws was performed in all patients.
Results: The mean age of the patients was 44 years with extremes ranging from 25 years to 54 years. The average number of history of nonunion cure failure was 1.4. All Pseudarthrosis was aseptic, atrophic, with osteopenia and bone lysis.
The mean size of the bone defect was 8.9 cm and the mean size of NVF removed was 11.4 cm. The radial nerve was transposed in 6 cases with 5 cases of iatrogenic motor involvement of the radial nerve. The evolution was favorable after 3 months.
The mean operative delay of IPHS was 2h55mn. The Consolidation was achieved in all patients. The average delay of consolidation of 7.8 months. All patients have resumed their former activities.
Conclusion: The challenge of patients with IPHS is the bone consolidation and the lost bone reconstruction. The NVF technique with dynamic and compressive DCP plate gives satisfactory anatomical and functional results in the management of multi-operated non-union.

Keywords: Humeral shaft, rebellious pseudarthrosis, narrow DCP screwed plate, cure of pseudarthrosis, consolidation

1. Introduction
Non-unions are one of the most feared complications of the treatment of humeral shaft fractures. Most non-unions of the humeral shaft are successfully treated with dynamic compression plate and bone graft addition. The consolidation rate is 82 to 95% [1]. Sometimes failures occurred. However, the frequency of non-unions of the humeral shaft can reach 12% in big series [2-4]. Failed treatment of humeral shaft pseudarthrosis or multi-operated pseudarthrosis are also called intractable pseudarthrosis of humeral shaft (IPHS) [5-7].
Their treatment requires a cure of the pseudarthrosis but also a reconstruction of the loss of bone and solid fixation. Reconstruction by using free fibula transfer is a technique of choice [8]. Several studies have shown the efficacy of the non-vascularized fibula (NVF) associated with solid and compressive fixation, in the management of multi-operated non-unions of the humeral shaft [9-12].
In our context of low-income countries, the use of the non-vascularized fibula with dynamic compression plate (DCP) fixation is a simple and effective technique in the management of intractable non-unions of the humeral shaft.

Our objective was to evaluate the anatomical and functional results of the surgical treatment of intractable pseudarthroses of humeral shaft using the non-vascularized fibula technique, at the Saint Jean de Dieu hospital of Afagnan.
Our hypothesis is that the anatomical and functional results are satisfactory in the short and medium term, after a cure of pseudarthrosis with a free fibula transfer.

2. Patients and Methods

2.1 Patients

This study involved patients aged over 15 years, who presented with an intractable pseudarthrosis of t humeral shaft between December 1, 2018, and December 31, 2022. We included all patients with intractable pseudarthrosis of the humeral shaft. with bone lysis, having at least one (01) history of failed treatment of pseudarthrosis for whom the initial lesion was caused by a trauma, and treated by the non-vascularized fibula technique with fixation by narrow DCP plate. This was a prospective and continuous study conducted in the same center involving 10 patients with 4 men and 6 women. The average age was 44 years [25-54]. Six patients had one history of failed treatment for pseudarthrosis of the humeral shaft and 4 patients had 2 histories of failed treatment. All patients had a standard radiography of the arm concerned (Fig 1). There was no damage to the radial nerve for all patients.

Fig 1: Atrophic intractable pseudarthrosis of the humerus

The radiological estimation of the size of the bone lysis gave an average of 6.7cm with extremes of 4cm and 12cm. CRP (C-reactive protein) was negative in all patients

2.2 Therapeutic protocol

The patients were placed in a supine position on a regular table under general anesthesia. The affected thoracic limb on arm table. The first stage consisted of a resumption of the initial approach which was lateral in all patients, with neurolysis followed by transposition of the radial nerve in cases where the nerve had not already been transposed. Then we processed for the removal of osteosynthesis material. The fibrosis of the pseudarthrosis site was excised and bacteriological sampling was made, then decortication was carried out. The medullary shaft was permeabilized, after resection of the sclerotic portions proximally and distally.
Assessment of the bone defect after resection of the sclerotic portions, allowed us to estimate the length of the fibular shaft witch will be removed (Figure 2).
The average size of the bone defect was 8.9 cm with extremes ranging of 6 cm and 14 cm.
The average size of the fibular graft was 11.4 cm with extremes ranging from 8 cm to 16 cm.

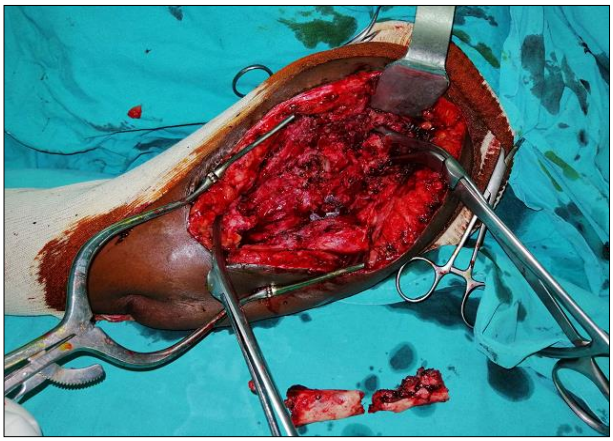

Fig 2: Lateral approach and excision of devitalized tissues

The second step consisted of removal the fibular shaft (Figure 3). This sample was taken from the contralateral leg under a pneumatic tourniquet at the root of the thigh (Figure 3)

Fig 3: Postoperative radiograph of the contralateral leg after fibular shaft removal.

The fibular shaft was interposed between the two ends of the humerus either intraductally or in a sarcophagus (Fig 4). Fixation was done with a DCP screwed with 4.5 mm cortical and/or cancellous screws. Closure was done under a suction drain.

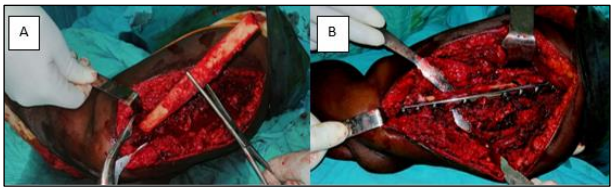

Fig 4: (A): Interposition of the graft between the 2 fragments of the humerus, B): Fixing with a DCP plate and 4.5mm screw.

The average of operative delay for intractable pseudarthrosis of the humerus was 175 minutes, with extremes ranging from 2 hours 05 minutes to 3 hours 30 minutes.
The average treatment delay, from the initial traumatic injury, was 19.3 (11 -36) months.
Antibiotic therapy was systematic. Active and passive rehabilitation began on the third day or even the seventh depending on the pain and the primary stability of the assembly.
The patients were regularly followed by clinically and radiologically. For some patients, a Sarmiento cast was made to protect the implant (Fig 5).

Fig 5: Functional rehabilitation: (A) = abduction, (B) = internal rotation

2.3 Evaluation of results

The evaluation of our results on an anatomical and functional level was made according to the scores: the WOS score (Western Orthopedic Society), taking into account patient satisfaction, severity of pain, elbow-shoulder mobility and the existence of a malunion (Table I) the second score we used was Stewart and Hundley (Table II) modified [13, 14].

Table 1: The WOS score

Satisfaction	Very satisfed – satisfied	3
	Disappointed – very disapointed	0
Pain	Absent or meteorological	6
	Minimum effort	4
	Important effort	2
	Permanent	0
Antepulsion	>120°	1,5
	90/120°	1
	<90°	0
Abduction	>120°	1,5
	90/120°	1
	<90°	0
External rotation	Normal	1,5
	Decreased	0
Internal Rotation	Normal	1,5
	Decreased	0
Elbaw Extension	<20°	1,5
	20/40°	1
	>40°	0
Elbaw Flexion	>130°	1,5
	110/130	1
	<110°	0
Radiography	Anatomical	2
	Cal>20°	0

Table 2: Stewart and Hundley scores

Very good	No pain
	Normal mobility
	Good radiological alignment
Good	No pain or climatic pain
	Shoulder and elbow stiffness less than 20
	Callus less than 20
Quite Good	Minor pain
	Stiffness of the shoulder and elbow between 20° and 40°.
	Callus greater than 20
Mauvais	Douleur persistance
	Raideur de l'épaule et du coude supérieure à 40°
	Pseudarthrose

3. Results

3.1 Anatomical results

All patients consolidated, in an average duration of 7.8 months with extremes ranging from 6 months to 9 months (Fig 6).

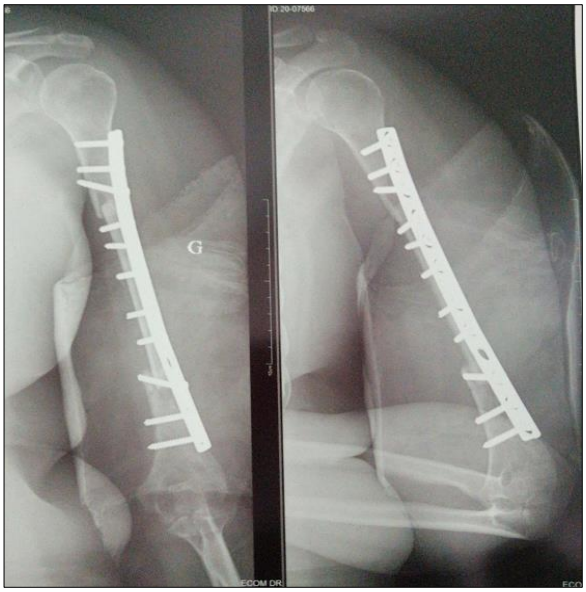

Fig 6: Control radiograph of the arm

Consolidation delay according to age

The delay of consolidation according to the age of the patients is listed in Table III

Table 3: Consolidation delay according to patient age

Age (Years old)	Consolidation delay		
	6 mois	9 mois	Total
[25-30]	1	0	1
[30-35]	1	0	1
[35-40]	1	1	2
[45-50]	1	2	3
[50-55]	0	3	3
Total	4	6	10

Secondary complications

We had in our study 5 cases of iatrogenic damage of the radial nerve. The recovery was achieved after three (3) months. We noted also one case of rotator cuff damage.
one case of disassembly of the plate proximally at the sixth postoperative month with a varus deformation of 20° and o, case of subacromial impingement.

3.2 Functional results

The functional results were satisfactory (Table IV) evaluated according to the score of the Western Orthopedic Society (WOS), are listed in Table IV.

Table 4: WOS score results

Score SOO (n=10)	Numbers
Very good	6
Good	3
Fair	1
Poor	0
Total	10

4. Discussion

We conducted a descriptive, prospective, monocentric, continuous study, which means that the statistical power of the study was low. Our series of 10 patients is statistically insufficient to make comparisons using statistical tests.
The vascularised fibula technique is not common in country, because of hard working conditions and poor technical platform. The non-vascularised fibular graft was then the better structural graft, available, less expensive, relatively easy to realize, with little or no morbidity at the donor site [15]. The particularity of our surgical technique was its simplicity, realize in one-step procedure, unlike the induced membrane technique user by Julien Gaillard *et al*. [7], which was a two-stage procedure.
Our method of interposition and fixation is similar to the method of Sudhir *et al*, and Kerfant *et al* on the other [8, 16], but the difference was in the use of the locked plate (LCP) unlike our technique where we used the dynamic compression plate (DCP). Complementary immobilisation with a directional splint or a brachial plaster cast, wrist in hyper-extension (if iatrogenic radial nerve damage) was put for 2 weeks, followed by a Sarmiento on the arm for 4 weeks (Fig 5).
In our study, There was more iatrogenic damage to the radial nerve than the series published by P. Boutroux *et al* and J. Gaillard *et al*. The recovery time (Table V) averaged was 3 months [5, 17].

Table 5: Iatrogenic damage of radial nerve after transposition and recovery time

Transposition of radial nerve	Number	Number of injuries	Recovery delay (Month)
P. Boutroux [17].	8	3	2
Julien Gaillard [5].	10	6	2 à 5
Our study	6	5	3

The arguments found in the literature in favour of transposition of the radial nerve are that, the nerve is further from the operating field, and that its straight course saves length and reduces tension on the nerve [8]. In addition to these arguments in the literature, our series showed an improvement in the average operative delay of pseudarthrosis cures depending on whether or not the nerve had been transposed. The average of operative delay was 197 min (3 h 17 mn) if the nerve had not been transposed against 143 min (2 h 23 mn) if the nerve had already been transposed. We then have a difference of 54 min (approximately 1 hour).

Average size of bone defect and fibular graft

In our study, we measured the size of the bone defect after resection of the sclerotic parts proximally and distally to the healthy zone in all patients. The mean size of the bone defect was 8.9 cm, with extremes ranging from 6 to 14 cm. This mean defect size was comparable to that found by N. Kerfant *et al* which was 8 cm with extremes ranging from 5 to 12 cm [8].
The size of the non-vascularised fibular graft depended on the size of the bone defect after resection. The mean length of the fibular graft was 11.4 cm, with extremes ranging from 8 cm to 16 cm. This mean length was comparable to that found in the literature, respectively 12, 13 and 10.7 according to Kerfant [8]. Gopisankar [18]. and Sreekanth [19] studies.
We also noted that cases of NFV interposition after sarcophagus placement, because of a narrower humeral canal, consolidated more rapidly than cases of direct intracanal interposition.
On 3 cases of direct intracanal interposition, none consolidated after 6 months, whereas of the 7 cases of intracanal NVF graft interposition after sarcophagus, 4 consolidated after 6 months and the other 3 after 9 months.

This observation may also be explained by the age of the patients, the osseointegration phenomenon and by a larger endo-medullary contact surface.

Anatomical results

At 12 months, consolidation was achieved in all patients, with an average delay of 7.8 months, ranging from 6 to 9 months. The average delay of consolidation varies in the literature: Five months and 5.4 months according to Kerfant [8] and Gopisankar [18] respectively. It was relatively longer in our series (7.8 months). These differences in consolidation delay could be explained by patients characteristics (Smoking, obesity, diabetes, alcoholism, hypertension, osteoporosis, nature of the pseudarthrosis), and also by the strength of the fixation (Locked compression plate, dynamic compression plate, number of screws on either side of the focus).

Functional results

According to Stewart and Hundley functional score, our results were very good in 3 cases, good in 4 cases and quite good in 3 cases. No poor results were noted in our series according to WOS score, or to Stewart and Hundley score. The functional results according to Steward and Hundley score found by Kesemenli *et al* are similar to our results: very good in 13 cases, good in 5 cases, and quite good in 2 cases. No poor results were noted [20].

Our functional results are consistent with those reported in the literature and demonstrate the efficacy of NVF with solid fixation in the functional prognosis of patients undergoing multiple operations for humeral pseudarthrosis.

Conclusion

The results of this study showed that the causes of pseudarthrosis of the humeral shaft are constituted by comorbidities of patient, and some risk factors, whether associated with surgical technique mistakes, lack of compression and lack of solidity of the fixation.

Our experience confirms the success of the intracanal NVF technique, with solid, compressive fixation using a DCP screwed with 4.5mm diameter, give consolidation in all patients. The mean delay of consolidation was 7-8 months.

The use of the non-vascularized fibula is justified in our context of lack of a bone bank. The advantages of this graft are it availability, biological, less expensive, without or little morbidity and with a high potential for consolidation. On the other hand, vascularized fibular grafting remains an attractive technique which requires a technical platform for its implementation.

Conflicts of interest: None

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