

# Prognostic factors in the treatment of carpal scaphoid non-unions

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Received: 20 September 2016 / Accepted: 24 October 2016 / Published online: 28 November 2016  
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**Abstract** In this literature review, the authors analyse the prognostic factors in the curative treatment of scaphoid non-unions. The main negative prognostic factors are smoking, the time elapsed since the fracture, and avascular necrosis of the proximal fragment. If the latter is present, the revascularization by a pedicle or microsurgical bone autograft is probably the treatment of choice. In non-unions without evidence of osteonecrosis, vascularized bone grafts are probably not superior to conventional bone grafts, which can presently be performed under arthroscopic control, with minimal morbidity.

**Keywords** Scaphoid non-union · Autograft · Prognostic factors

## Introduction

Scaphoid fractures are believed to heal in over 85%, if properly immobilized or fixed.

Conversely, scaphoid Non-Unions (NUs) result from inadequate, absent or too short immobilization, or in the case of important interfragmentary motion as occurs when the original fracture is displaced more than 1 mm, with or

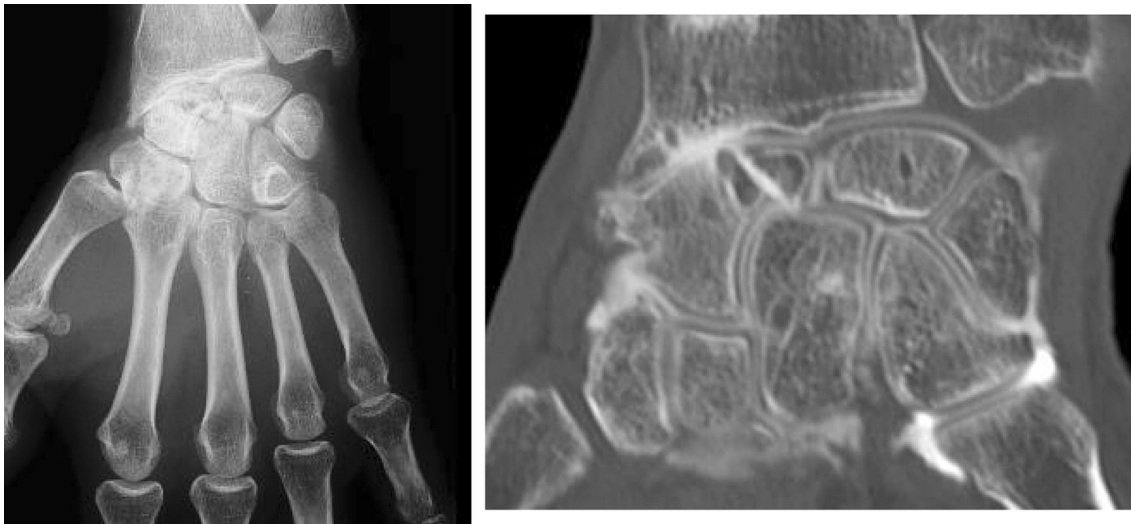
without carpal instability. Proximal fractures are also prone to NU.

Scaphoid NU is actually a not well-defined concept, but most authors agree that a NU exists if there is no evidence of scaphoid healing, at least 3 months after the initial fracture. Some scaphoid NUs cause few symptoms and little disability, and surgical treatment is in such cases probably not justified. As demonstrated by Moritomo et al. [1], stable NUs are those with the fracture line proximal to the scaphoid apex (the scaphoid apex is the most dorsal and ulnar non-articulating part of the scaphoid). In these stable NUs, the dorsal intercarpal and the dorsal scapholunate ligaments insert on both proximal and distal scaphoid fragments, and because there is minimal interfragmentary motion, the NU does not aggravate over time. Most NUs are unstable and their natural history is progressive arthritic changes over time, referred in the literature under the term “Scaphoid Non-union Advanced Collapse” (SNAC): initially non-displaced NUs become displaced, with progressive dorsal intercalated segment instability (DISI) deformity. The osteoarthritis, initially involving the distal scaphoid fragment—radial styloid joint—progresses to the scapho-capitate and capitulate joints. The proximal radio-scaphoid and radio-lunate joints remain spared (Fig. 1). The hyaline cartilage degeneration seems to be related to joint incongruence after displacement of the non-united distal scaphoid fragment, causing abnormally high articular stresses. So after some years, most scaphoid NUs evolve into painful advanced wrist osteoarthritis, causing handicapping pain and reduced hand function. Healing the isthmic scaphoid NU before carpal degeneration, restoring the shape of the bone and its ligament connections, seems therefore the best option to offer to the affected patient, but even with the best surgical skills, failure to heal the NU remains possible. The operation usually imposes prolonged

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**Fig. 1** Typical SNAC wrist. Note the absence of osteoarthrosis at radio-lunate joint and at the articulation between the distal radius and the proximal scaphoid pole

plaster cast immobilization and is not devoid of complications. The surgeon may consider instead, especially in the presence of an old scaphoid NU with a humpback deformity and already some evidence of joint degeneration, some form of palliative surgery, for example first carpal bone resection, leading to a quicker yet acceptable functional result, however on the long term not comparable to the one that can be obtained after restoration of normal carpal anatomy and function [2–4]. The surgeon and the patient should therefore know what are nowadays the actual chances to heal a scaphoid NU, using a vascularized or a conventional (open or endoscopic) bone graft, by isolated bone internal fixation, or in most cases by combined bone grafting and osteosynthesis.

One of the authors (FS) has published with associate authors in 1999 a well-cited paper, reporting the prognostic factors in the curative treatment of scaphoid NUs [5]. The results were based on a retrospective multicentric study of 138 scaphoid NUs—the cases had been contributed by specialized surgeons of Belgium, Spain and Switzerland. The patients had been treated by isolated conventional bone grafting, by internal fixation, or by combined bone grafting and internal fixation, and the mean follow-up duration was 38.8 months (median 17 months). Scaphoid bone healing had occurred in 75%. In the group of failures, the clinical and radiologic results were significantly worse, suggesting that the patients had been aggravated by the failed surgical attempt to heal the NU. In multivariate analysis, the only predictor factor was the time elapsed between the initial fracture and the treatment of the established NU. When this delay exceeded 5 years, the chances of healing the NU were decreased. Among the 97 cases of internal fixation (with or without bone grafting), the only predictor was the importance of bone resorption.

Since the publication of this article, many advances have been made. Computed tomography scans are now routinely used to assess bone healing, and it is possible that some cases of possible persistent NUs of our series were actually healed, or the reverse, some cases considered healed on X-rays were actually in a state of tight NU. Magnetic resonance (MR) is now available to better assess the presence or not of proximal pole avascular necrosis (AVN) [6–8]—in our 1999 study, the diagnosis of osteonecrosis was based upon evidence of radiological osteocondensation. We know, however, that increased bone density suggests but does not prove bone devascularization. In 1999, vascularized bone grafts (VBGs) were not commonly performed for scaphoid NUs; pedicled or microsurgical VBGs are now routine procedures (Fig. 2) and are especially recommended in the case of proximal pole AVN [9–28]. On the other hand, non-vascularized bone grafts (NVBGs) can now be done under arthroscopic control [29, 30]. Finally, the detrimental role of tobacco now well established in general bone healing [31] had not been suspected in 1999. The purpose of the present article is, based on a review of the recent literature, to actualize the conclusions of our study and to determine which factors, related either to the patient, to the NU or to the treatment, seem important predictors to determine whether the cure of an isthmic scaphoid NU has reasonable chances to lead to bone healing, or instead whether palliative surgical alternatives such as wrist denervation, first carpal row resection, intercarpal fusion, prosthetic arthroplasty or total wrist fusion should be considered. We do not discuss in this article very proximal or very distal NUs, which represent different clinical entities with specific problems.



**Fig. 2** Proximal isthmic scaphoid non-union healed by Zaidemberg (1,2-intercompartmental supra-retinacular pedicle distal radius) VBG

## Materials and methods

The English literature of the last 20 years has been reviewed, and data about possible prognostic factors have been searched for.

## Results

### Prospective, randomized studies

Singh et al. [32] investigated whether gadolinium-enhanced MR could predict the outcome of scaphoid NU operations, but no relationship was found between pre-operative MR imaging and the outcome of surgery. Goyal et al. [33] compared 50 patients treated by NVBG's from distal radius to 50 patients where the bone graft originated from the iliac crest and could not find any significant difference between both groups. Ribak et al. [34] and Caporrino et al. [35] prospectively compared in their studies pedicle VBG's and NVBG's from the distal radius to treat scaphoid NUs. Ribak found better healing rate after VBG (46 patients, healing rate 89.1%) than after NVBG (40 patients, healing rate 72.5%). The benefits of VBG's were especially obvious in sclerotic, poorly vascularized scaphoid. Based on 75 cases, Caporrino found slightly (not clinically meaningful) quicker bone healing, when using VBGs.

### Meta-analyses

Several excellent meta-analyses can be found in the literature. An early meta-analysis from Merrell et al. [36] concluded first that in unstable NUs treated by NVBG, screw fixation leads to superior bone union (94%) than

Kirschner-wire fixation (77% union). Second, in the case of AVN of the proximal fragment, union was achieved in 88% with a VBG, versus 47% with a NVBG. Thirteen years later, Pinder et al. [37] published another meta-analysis of 1602 patients, treated either by VBGs or NVBGs. They concluded that VBGs were not clearly superior to NVBGs, and that bone autografts harvested from the iliac crest lead to similar union rates than those harvested at the distal radius, but with increased morbidity. Osteosynthesis was associated with higher union rate than without bone fixation; patients fixed with screws were mobilized earlier than those with K-wires.

Other published meta-analyses have dealt with technical aspects of treatment of scaphoid NUs. Sayegh and Strauch [38] compared cortico-cancellous and purely cancellous NVBGs to heal scaphoid NUs. The first types of grafts allowed better deformity correction and functional results, while the latter allowed shorter bone healing union duration. Ditsios et al. [39] found that microsurgical periosteal VBGs allowed better scaphoid healing rate than pedicle VBGs, and Al-Jabri et al. [40] reported that microsurgical periosteal bone graft from the medial condyle allowed better healing rate (100%) than microsurgical VBGs from the iliac crest (88%).

### Comparative studies

Euler et al. [41] presented a retrospective study of scaphoid NUs with humpback deformity and DISI, comparing early (within 1 year of the initial fracture) and late reconstruction (>1 year) by anterior wedge NVBG. In the early reconstruction group, bone union and correction of DISI deformity could be achieved in all patients. In patients treated 1 year or more after the original fracture, the union rate was 60%, without correction of the DISI deformity at final follow-up

and without important functional improvement. Jones et al. [16] performed a retrospective study comparing two techniques of VBGs, distal radial pedicle VBG and microsurgical-free VBG from the femoral condyle, in cases with proximal pole AVN and carpal collapse. The rate of union was significantly higher, and the median time to healing significantly shorter, with the medial femoral condyle graft.

### Prognostic factors based on individual series

Most published series are relatively small series of scaphoid NUs, treated by one single method, usually with good success rate, and the authors were not able to report factors associated with success or failure. However, Little et al. [42], and later Dinah and Vickers [43] clearly established the deleterious role of tobacco on scaphoid healing after treatment of scaphoid NUs by NVBG. In the series of Little, the rate of union was 73.4%, but 13 of the 17 persistent NUs occurred in smokers ( $p < 0.01$ ). In the series of Dinah, the success rate was in non-smokers 82.4%, dropping to 40.0% among smokers ( $p < 0.01$ ). Also, Hirche et al. [44] reported that smoking was a risk factor of failure.

We reported that the delay between the initial trauma and the treatment of the established NU was the most important prognostic factor to consider [5]. Shah and Jones [45] found as well in a series of 50 patients treated by wedge NVBG and screw fixation, a union rate of 88% if the operation had been performed within 5 years of the initial injury, dropping to 57% for older NUs. Nakamura et al. [46] reported poor outcome in NUs older than 5 years. However, bone healing can still be obtained years or even decades after the initial trauma [35, 47].

Most of the failures in the series of 58 scaphoid NUs treated by NVBG technique of the series of Chantelot et al. [48] occurred in cases with proximal pole AVN, and the authors concluded that for patients with a necrotic proximal pole, a VBG would have been preferable. In an early series of 10 patients treated by VBGs, Boyer et al. [49] reported bone healing in the six patients who had not been previously operated. In their series of 50 scaphoid NUs treated with pedicle VBGs, with a 68% union rate, Chang et al. [50] reported in univariate analysis the following risk factors for failure: female gender, older age, tobacco use, proximal pole AVN, pre-operative humpback deformity and non-screw fixation. In another series of 75 patients, also treated with pedicle VBGs, with a 72% union rate, Werdin et al. [51] did not find that age, smoking, duration of disease nor previous operation had an impact on the healing.

## Discussion

Several factors are probably important to consider when treating a scaphoid NU, with the aim to obtain bone healing before joint degenerative changes. These factors are associated either with the patient, with the NU, or the type of treatment.

### Patient's predictors

The age and gender of the patient do not seem to be important factors. Smoking clearly reduces the chances to heal the scaphoid NU. It seems reasonable to advise the smoker patient to discontinue tobacco before and after the operation aiming at healing the scaphoid NU.

### Non-union's predictors

Several studies confirmed that the delay between the initial trauma and the treatment of the established NU is an important prognostic factor to consider. The chances to heal the scaphoid NU decrease over time, already after 1 year, but especially after 5 years—but this does not mean that bone healing cannot be obtained later on, in selected cases, nor that it will not anymore if it occurs help the patient [52]. Also, adequate correction of the humpback deformity and DISI becomes more and more difficult in older NUs. Previous surgery seems also a negative prognostic factor.

AVN of the proximal pole, present in 3% of non-united scaphoid fractures [12], seems an important prognostic factor, although increased radiographic density of the proximal pole had not been found prognostic in our 1999 study. MR imaging suggesting AVN seems not very reliable. Green [53] demonstrated in a prospective study of patients treated by NVBG (Russe technique) solid bone union in 24 of 26 patients (92%) when there was no evidence of AVN; with proximal pole avascularity, none of the five patients healed. Green recommended to evaluate pre-operatively the status of proximal pole vascularity, by observing punctate bleeding points on the cancellous surface, after removal of the tourniquet. Many authors, therefore, strongly recommend the use of a VBG, when there is pre- or per-operative evidence of proximal fragment avascularity, which makes sense and is supported by basic science studies [54–56]. However, a prospective randomized study is still lacking to support this attitude.

The existence of pre-operative carpal collapse, DISI or osteoarthritis does not seem to contraindicate curative treatment options—but the surgery will not cure the degenerative phenomena; on the contrary, they can be



aggravated despite scaphoid healing. Important scaphoid resorption is a prognostic factor in case of screw fixation.

### Treatment's predictors

Bone autografts harvested from the iliac crest do not seem to be superior to those from the distal radius and cause increased morbidity. VBGs have become popular, and many authors have postulated that these techniques allow better scaphoid healing. Like others, we use pedicle VBGs in most scaphoid NUs (Fig. 2). Not too many studies, however, demonstrate the superiority of VBGs over NVBGs. The prospective study of Caporrino et al. [35] and the meta-analysis of Pinder et al. [37] do not confirm that VBGs are better, although these techniques probably shorten the healing duration [20, 21]. Although most authors have presented a high rate of bone healing after VBG (frequently 90% or more), some have reported unsatisfactory results [57]. The VBG techniques are technically more difficult than the classical NVBGs, the latter allowing easier correction of the scaphoid humpback deformity and osteosynthesis by a screw instead of Kirschner wires, allowing earlier post-operative mobilization. NVBGs can presently be performed by minimally invasive technique, under arthroscopic control. If the choice is to perform a VBG, particularly in the case of proximal pole AVN, then microsurgical periosteal bone grafts from the femoral medial condyle, though technically demanding, imposing general anaesthesia and two surgical teams, and not devoid of complications as ectopic bone formation [40, 58], seem to provide better bone healing than pedicle VBGs. It should be recalled here that not all scaphoid NUs require a bone graft. Those well aligned and without marked bone resorption can well be treated with internal fixation alone [59] or even by external fixation [60].

In conclusion, many questions remain unsolved, justifying the initiation of a prospective multicentre study. The main negative prognostic factors when trying to heal a scaphoid NU are probably tobacco, the time elapsed since the fracture, and the existence of proximal pole AVN. Uncertainties remain concerning the best treatment options. VBG's should probably be recommended in the case of pre-operative proximal pole AVN.

### Compliance with ethical standards

**Conflict of interest** None.

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