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Validation of the Non-Union Scoring System in 300 long bone non-unions

G.M. Calori [a,*], M. Colombo [a], E.L. Mazza [a], S. Mazzola [a], E. Malagoli [a], N. Marelli [a], A. Corradi [b,c]

[a] C.O.R. Reparative Orthopaedic Surgery Department, Orthopaedic Institute Gaetano Pini, University of Milan, Italy
[b] Academic Department of Trauma & Orthopaedic Surgery, School of Medicine, University of Milan, Italy
[c] I.R.C.C.S. Policlinico San Donato, Piazza E. Malan, 20097, San Donato M.se, MI, Italy

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ABSTRACT

Introduction: Non-union of long bones is a significant consequence of fracture treatment. The ideal classification for non-union of long bones would give sufficient significant information to the orthopaedic surgeon to enable good management of the treatment required and to facilitate the creation of comparable study groups for research purposes. The Non-Union Scoring System (NUSS) is a new scoring system to assist surgeons in the choice of the correct treatment in non-union surgery. The aim of this study was to determine the evidence supporting the use of the NUSS classification in the treatment of non-unions of long bones and to validate the treatment algorithm suggested by this scoring system.
Materials and methods: A total of 300 patients with non-union of the long bones were included in the clinical study.
Results: A radiographic and clinical healing was reached in 60 of 69 non-unions (86%) in group 1 (0–25 points), in 102 of 117 non-unions (87%) in group 2 (26–50 points), and in 69 of 84 (82%) in group 3 (51–75 points). The mean time to clinical healing was 7.17 ± 1.85 months in group 1, 7.30 ± 1.72 months in group 2 and 7.60 ± 1.49 months in group 3. The mean time to radiographic healing was 8.78 ± 2.04 months in group 1, 9.02 ± 1.84 months in group 2 and 9.53 ± 1.40 months in group 3.
Discussion: There are few articles in the scientific literature that examine the classification systems for non-union.
Conclusions: A statistical analysis of the first results we have obtained with the use of NUSS showed significant rates of union in all the evaluated groups. This indicates that NUSS could be an appropriate scoring system to classify and stratify non-unions and to enable the surgeon to choose the correct treatment.

Introduction

Definition

Non-union refers to a fracture that will not heal without an additional surgical or non-surgical intervention (usually by 6–9 months). According to the US Food and Drug Administration (FDA), the diagnosis of non-union may be established "when a minimum of 9 months has elapsed since injury and the fracture shows no visible progressive signs of healing for 3 months". The timeframe, however, is different for each kind of fracture: a fracture of the tibial shaft is usually not considered a non-union until at least 9 months, whereas a fracture of the femoral neck can be defined as a non-union after only 3 months. Among the long bones, the tibia is the most common site for the development of non-union. The current failure rate in non-union surgery is approximately 20% [1]. To address all the factors that may be implicated in fracture non-union, several elements need to be considered, including the cellular environment, growth factors, bone matrix and mechanical stability; these comprise "the diamond concept" [2], which has further evolved into "the regenerative pentagon" when vascularisation is also considered [3].

* Corresponding author at: Reparative Orthopaedic Surgery Department, Orthopaedic Institute Gaetano Pini, University of Milan, P.za Cardinal Ferrari 1, 20122 Milan, Italy. Tel.: +39 0258296904; fax: +39 0258296905.
E-mail address: gmc@studiocalori.it (G.M. Calori).

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Classification

The most widely used classification for non-union is the Weber–Cech system, which classifies the non-union according to radiographic appearance, and this correlates with the biology of the fracture [4]. The Weber–Cech classification recognises the following types of non-union: hypertrophic non-union, which has excellent healing potential due to abundant callus formation and hypervascularity; oligotrophic non-union, which is vascularised with no callus formation; and atrophic non-union, in which there is an absence of callus formation, atrophic bone stumps and deficient bone vascularity.

Another classification was made by Ilizarov, who classified non-unions into two categories: lax and stiff [5]. Radiologically, a "lax non-union" has an atrophic bone stump that exhibits a pathological movement more than 7° and a shortening of more than 2 cm. A "stiff non-union" has a hypertrophic bone stump, a pathological movement of less than 7° and a shortening of less than 2 cm. A further classification was described by Paley and Herzenberg in terms of clinical mobility and has two main types: type A, which is bone defect of less than 1 cm, and type B, which is bone defect of more than 1 cm [6].

The current authors have recently defined different risk factors that are implicated in the pathogenesis of fracture non-union. These risk factors can be separated into general factors (sex, age, diet, diabetes, osteoporosis, muscular mass, smoking, alcohol, drugs) and local factors (fracture personality, type of fracture, exposure, infection, multiple trauma/fractures) [7–12]. The purpose of this exercise is to develop a new scoring system that considers all the risk factors to assist surgeons in the complex analysis of non-unions before conducting surgery. In 2008, we published a new classification for non-unions: the Non-Union Scoring System (NUSS) [13]. For too long patients with non-union were hardly compared with each other. With our new classification, we have attributed precise clinical and radiographic values to compare the outcomes of patients with fractures of similar complexity. The NUSS considers the bone quality, typology of primary injury, number and invasiveness of previous interventions, adequacy of previous surgery, Weber–Cech classification, bone alignment, presence of bone defect, state of the soft tissues, American Society of Anaesthesiologists (ASA) grade of the patient, and specific clinical characteristics of the patient, including clinical infection status, smoking status, use of drugs, parameters of specific blood tests (white cell count, erythrocyte sedimentation rate, C-reactive protein) and diabetes. The total score is multiplied by two. All the factors included in the scoring system have an impact on the complexity and difficulty of treatment of any non-union [14–17] (Table 1).

The NUSS recognises four groups according to severity (Fig. 1):

- Score from 0 to 25 should be considered a straightforward non-union and should respond well to standard treatments; usually the problem is mainly mechanical. The common aim of treatment is to improve stability, usually choosing a different system of fixation.
- Score from 26 to 50 should require more specialised care; usually the problem is both biological and mechanical. The treatment requires the correction of the fixation associated with a biological stimulation obtained with pulsed electromagnetic fields (PEMF), extracorporeal shock wave therapy (ESWT) or biotechnologies, such as mesenchymal stromal cells, growth factors or scaffold, in monorail therapy [18–30].
- Score from 51 to 75 requires specialised care and specific treatments. The problem is complex and is characterised by impairment of both biological and mechanic conditions.

Table 1
Non-Union Scoring System (NUSS). The total score is multiplied by two; it provides an index of severity of non-union from 0 to 100 points. A high score indicates a greater complexity.

	Score
Bone	
Quality of the bone	
Good	0
Moderate (e.g. mildly osteoporotic)	1
Poor (e.g. severe porosis or bone loss)	2
Very poor (necrotic, appears avascular or septic)	3
Primary injury-open or closed fracture	
Closed	0
Open 1° grade	1
Open 2°–3° grade (a)	3
Open 3° grade (b–c)	5
Number of previous interventions on this bone to procure healing	
None	1
<2	2
<4	3
>4	4
Invasiveness of previous interventions	
Minimally-invasive: closed surgery (screws, k-wires, etc.)	0
Internal intra-medullary (nailing)	1
Internal extra-medullary	2
Any osteosynthesis that includes bone grafting	3
Adequacy of primary surgery	
Inadequate stability	0
Adequate stability	1
Weber and Cech group	
Hypertrophic	1
Oligotrophic	3
Atrophic	5
Bone alignment	
Non-anatomical alignment	0
Anatomical alignment	1
Bone defect – gap	
0.5–1 cm	2
1–3 cm	3
>3 cm	5
Soft tissue	
Status	
Intact	0
Previous uneventful surgery, minor scarring	2
Previous treatment of soft tissue defect (e.g. skin loss, local flap cover, multiple incisions, compartment syndrome, old sinuses)	3
Previous complex treatment of soft tissue defect (e.g. free flap)	4
Poor vascularity: absence of distal pulses, poor capillary refill, venous insufficiency	5
Presence of actual skin lesion/defect (e.g. ulcer, sinus, exposed bone or plate)	6
The patient	
ASA grade	
1 or 2	0
3 or 4	1
Diabetes	
No	0
Yes (well controlled hba1c < 10)	1
Yes (poorly controlled hbac1 > 10)	2

Blood tests: FBC, ESR, CRP	
FBC: WCC > 12	1
ESR > 20	1
CRP > 20	1
Clinical infection status	
Clean	0
Previously infected or suspicion of infection	1
Septic	4
Drugs	
Steroids	1
Nsaids	1
Smoking status	
No	0
Yes	5

Abbreviations: ASA = American Society of Anaesthesiologists; HbA1c = glycosylated haemoglobin level; WCC = white blood cell count; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; NSAIDs = non-steroidal anti-inflammatory drugs.

Resection of the non-union is usually required and consequently a bone defect must be treated. Traditional treatments may be used, such as bone transport with external fixator, autologous iliac crest grafts or microvascular fibula grafts; however, also indicated are biotechnological products, including cells, scaffold and growth factors, according to the principles of the "biological chamber" [31,32] and "polytherapy" [33–36].

- Score from 76 to 100 may indicate the need for primary amputation, arthrodesis, prosthesis or mega-prosthesis implantation depending on the patient's condition, the severity of the bone loss and the anatomical localisation [37].

This system has not yet been widely validated, but many clinicians have adopted the NUSS for use in their clinical practice and in scientific studies in the field of non-union.

Materials and methods

Study design

This is a retrospective clinical study conducted in our department at Orthopaedic Institute G. Pini (University of Milan). We retrospectively reviewed our database from January 2013 and selected the last 300 patients treated for long bone non-unions. The aim of this study was to evaluate the appropriateness and efficacy of the NUSS classification in the treatment of non-union of long bones, and particularly to assess that a classification based on both the radiological aspect of the non-union and the general characteristics of the patient could be superior to the traditional classification of Weber–Cech. A further objective of the study was to validate the treatment algorithm suggested by our classification.

Patients

Inclusion criteria were: age over 18 years, presence of long bone non-union and able to follow the requirements of the follow-up.

Exclusion criteria were: pregnancy, skeletal immaturity, any immunosuppressive drug therapy, autoimmune disease, neoplasia and mental health problems.

A total of 300 patients with non-union of long bones were included in the clinical study. There were 198 male (66%) and 102 female (34%) patients. The mean age ± standard deviation was 45.94 ± 14.59 years (range from 19 to 73 years). Non-union was of the tibia in 52% of patients, the femur in 17%, the humerus in 11%, the radius in 6% and the ulna in 4%. Study tasks included assessment of case history, acquisition of radiographs, prescription of a CT scan (in some cases) and blood tests.

The patients were divided into four groups according to the NUSS classification: group 1 comprised 69 patients, who underwent standard treatment (average NUSS 18.34 ± 5.36); group 2 had 117 patients, who received monorail therapy (average NUSS 39.15 ± 7.52); group 3 included 84 patients, who received polytherapy (average NUSS 64.07 ± 5.25); and group 4 contained 30 patients, who received specialised care: prosthesis in 15 patients, megaprosthesis in 12 patients, arthrodesis in two patients and amputation in one patient (average NUSS 77.8 ± 1.66).

Outcome assessments

Both radiological and clinical evaluations were assessed. All patients were followed up at 1, 3, 6, 9, 12 and 18 months after the primary treatment. The clinical success was evaluated by the

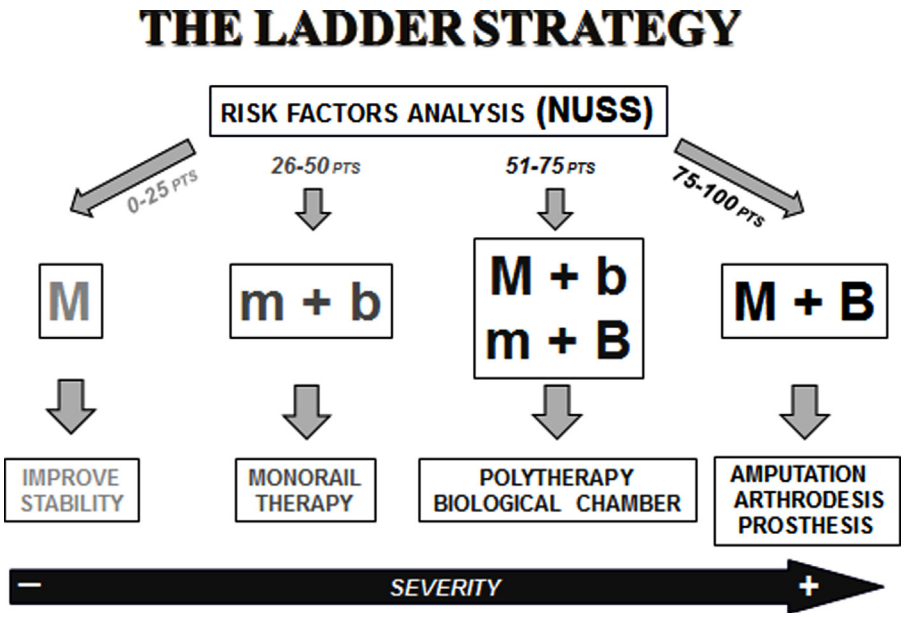

Fig. 1. Algorithm of choice of treatment for non-union and bone defect based on the Non-Union Scoring System (NUSS), which recognises four groups of severity. This treatment algorithm is based on the concept of a "ladder strategy": for a simple problem there should be a simple answer, whereas a more serious problem corresponds to a more complex solution. Abbreviations: M = major mechanical problem; m = minor mechanical problem; B = major biological problem; b = minor biological problem.

absence of pain in the treated bone segment, the finding of a range of motion (ROM) of the joint related to the treated bone that is similar to the contralateral site, and recovery of usual activities or work. Radiological success (evaluated with X-ray or CT-scan) was considered based on the presence of bridging callus (3/4 of cortical) in both anteroposterior and lateral views.

Results

Clinical and radiological healing rate was evaluated only in the first three classes of the NUSS; the 30 patients classified in the fourth group were excluded from this evaluation because it was not possible to evaluate the biological restoration of the bone defect. Healing was reached in 60 of 69 non-unions (86%) in group 1, in 102 of 117 non-unions (87%) in group 2, and in 69 of 84 non-unions (82%) in group 3. The mean time to clinical healing was 7.17 ± 1.85 months in group 1, 7.30 ± 1.72 months in group 2 and 7.60 ± 1.49 months in group 3. The mean time to radiographic healing was 8.78 ± 2.04 months in group 1, 9.02 ± 1.84 months in group 2 and 9.53 ± 1.40 months in group 3.

The complications observed in the series were as follows. In group 1, the fixation device failed in three patients and was replaced with bone graft harvested from the iliac crest; in another six patients, there was no sign of healing at the last follow-up, so these patients underwent further surgery using a new synthesis supported by bone graft from the iliac crest. In group 2, three patients had infections at the site of bone harvesting from the iliac crest and these were treated with antibiotics; six patients were lost to final follow-up, and six patients required further surgery with the use of biotechnology. In group 3, three patients were lost to final follow-up; nine received megaprosthesis; and three patients underwent amputation. In 12 patients (six in group 2 and six in group 3), pain developed at the donor site at the iliac crest up to one year after surgery.

A statistical analysis of the first results we have obtained with the use of NUSS showed significant rates of union in all the evaluated groups. This indicates that the NUSS could be an appropriate scoring system to classify and stratify non-unions and to enable the surgeon to choose the correct treatment.

Discussion

There are few articles in the scientific literature that examine the classification systems for non-union. Megas [38] published an article in 2005 that presented the classification of Weber–Cech and mentioned a revised protocol of classification made by Chi-Chuan and Wen-Jer, which utilised both radiographic observation and fixation stability. The non-unions that were considered to have stable fixation were classified into the avascular/anthropic type and the non-unions that were considered to have unstable fixation were classified into the hypervascular/hypertrophic type.

Frolke and Patka [39] published a paper in 2007 on the definition and classification of non-unions in which they included the classification of Weber and Cech and the classification by Paley et Herzenberg.

We published our classification, the NUSS, in 2008. Our classification was used subsequently in all the work we have published in the field of non-union. In 2011, Abumunaser [40] published a study with the aim to evaluate the validity of our NUSS in the treatment of non-unions. A retrospective database review for lower extremity non-union was conducted and 40 patients were identified. The patients were divided into three groups according to treatment: group 1 (0–25 points), standard treatment, group 2 (26–75 points), specialised care and treatment, and group 3 (76–100 points), amputations. Statistical analysis showed significant correlation between the treatment on the database and those recommended by NUSS. Abumunaser concluded that NUSS could be a valid guideline for treatment of lower extremity non-union.

Conclusion

The ability of the surgeon to judge a non-union is traditionally based on standard imaging, symptoms and clinical examination; these simple tools are usually inadequate to classify a non-union. After the identification of the risk factors, there are multiple tools available to clinicians derivable from the clinical history, blood tests and radiological examinations for a complete evaluation of the complexity of the non-union. Our classification considers the whole patient in their complexity and not only the affected bone to give a severity score. After the publication of the NUSS, many orthopaedic departments worldwide have decided to adopt our classification for the management of this pathology. The NUSS has not yet been validated; however, we suggest that this classification is adopted by as many centres as possible to generate a common database with the aim to collect sufficient clinical cases to validate the classification. The main strengths of the NUSS are that it is the first classification of non-unions that considers the type of the non-union and also the characteristics of the patient, and it was created with supporting evidence from the literature. The main weakness of NUSS is the lack of validation, so we encourage all orthopaedic centres to utilise our classification and share the treatment results in a common database.

Conflict of interest

The authors declare that they have no conflicts of interest concerning this article. No financial support has been received by the authors for the preparation of this manuscript.

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