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Classification of non-union: Need for a new scoring system?

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Summary A new scoring system is proposed in order to assist surgeons with the complex analysis associated with non-union surgery. Patients with non-union are rarely easily compared with one another and this has frustrated research in this field. We have therefore attributed values to clinical features based on clinical experience and research evidence, so that patients of similar complexity can be compared with one another. When greater experience with this scoring system has been gained it will be further refined and validated. We propose that surgeons with a sub specialist interest in non-union surgery use this system in reporting results, and that non-specialist surgeons use it to inform their decision to treat the fracture themselves, or refer to a sub specialist.

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Introduction

There has long been debate about the definition of non-union. Even if current definitions are accepted, the problem is not simple and fails to provide a satisfactory definition of non-union. This concept has hindered research into non-union for many years as no two cases of non-union are apparently alike. The concept of the 'personality of the fracture' has been previously described as the need to consider first the bone, then the soft tissues, the patient and the environmental factors that influence the patient's response to the fracture.¹ We propose that a similar approach to fracture non-union is required so that (a) results for non-unions of similar severity can

be compared, and (b) a better understanding of the problem will allow us to direct our treatment strategy more objectively. This would be similar to the purposes of other scoring systems, such as the Injury Severity Score or the multiplicity of functional scoring systems available for grading joint disease.² In this context, we have taken into account important variables that have been implicated in the pathogenesis of non-union. After consulting a number of our colleagues, we present a new scoring system for grading non-union of fractures.

Evolution of the new Non-Union Scoring System (NUSS)

Classification systems for non-union in the past have been described. Weber and Cech³ developed a system based on radiographic appraisal, which

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is widely used to inform decision-making in non-union surgery. This system has not been validated to our knowledge. Indeed, there have been reports that the assumptions made by Weber and Cech are not supported by recent scientific evidence.⁴ Close scrutiny of many publications in non-union surgery will reveal that surgeons and ethics committees do not feel that hypertrophic non-unions should not be bone grafted.^{5,6}

Ilizarov developed a system in order to select the appropriate surgery to be performed, based on some aspects of the bone morphology (lax, stiff and stiff with angular deformity).⁷ Each patient can only fit into one group, and only one treatment is appropriate for each group. We are not convinced that this system meets the requirements of non-union treatment now, because there are more options for treatment than the systems Ilizarov used, and clearly this does not take the whole fracture personality into account.

Paley described an extremely useful system for the classification of non-union for the purposes of reconstruction, but again, whilst this informs the surgeon with respect to which technique may be most appropriate, it does not take the whole situation into account.⁸ An improved system would need to take account of the multitude of factors that the pragmatic orthopaedic traumatologist needs to analyse in order to make a final decision, having to choose from a wide range of treatment options.

Current failure rates in non-union surgery run at around the 20% level.⁹ It has been proposed that in order to address all the factors which may be implicated in a fracture non union, the elements to be considered are the cellular environment, the growth factors, the bone matrix and the mechanical stability the so-called 'Diamond Concept'.¹⁰ Vascularity of fracture non unions was assumed to be deficient in the 'biologically inactive' group of Weber and Cech, but evidence for this has been called into question.⁴ Whether vascular insufficiency is a crucial factor remains to be addressed. If we assume that the cause for failure of non-union surgery is a failure to fully appreciate all of the factors involved, then we hope that adoption of this scoring system will help in the long term to establish some guiding principles of classification and treatment.

As discussed above, previous scoring systems have been largely based on radiographic appraisal of non-union. This is clearly an important factor, but it would be sensible and more valid to make an assessment on wider grounds if possible. Although surgeons use radiographs to inform decision

making quite rationally on the basis of gap size, alignment, geometry/stability, porosis, sclerosis, there are other factors which the radiograph does not inform including high/low energy mechanism of trauma, concurrent disease such as diabetes, steroid therapy, namely vascularity, presence of infection, the cellularity, the gene expression and the receptor status of the cells, the chemical environment, the wider 'personality of the non-union', and the history of the previous treatment modalities.¹¹⁻¹⁹

Bhattacharrya et al. elegantly showed that surgeons cannot even judge 'better than a coin-flip' whether a fracture is united or not in suspected non-union cases based on plain radiographs of non-unions.²⁰ We should therefore be cautious about how much more information we believe we can derive from plain films alone.

What other factors should be appraised? Hinsley et al. have established that laser Doppler flowmetry is not useful in assessment of open fracture bone fragment viability, and is therefore not likely to be useful for non-union assessment.²¹ We have not been able to find any work on the usefulness of MR or angiography in long bone fracture non-union, though it has been used in the assessment of bone perfusion in the femoral head after femoral neck fracture to predict outcome of fixation surgery.²²

It may be that we should consider bending stiffness and/or callus index²³ or other innovative techniques.^{24,25} However, in the current clinical environment, these tests do not form part of the daily armamentarium of the traumatologist and for reasons of pragmatism, these factors have not been included in our scoring system.

It is therefore with this wide remit that we propose that factors in the development of a new scoring system should include the bone quality, original fracture characteristics being closed or open, number of previous interventions, invasiveness of previous interventions, adequacy of previous surgery, bone alignment, presence of bone defect, the state of the soft tissues and the American Society of Anesthesiologists (ASA) grade of the patient (Table 1). Each factor has been broken down into subgroups each provided with a scoring system reflecting the difficulty that one can expect during the course of treatment.

The total score would then be multiplied by 2. We would then suggest that scores from 0 to 25 would be considered straightforward non-unions and should respond well to standard treatments. Scores from 26 to 50 would require more specialised care to be considered. For patients with scores from 51 to 75, specialised care and

Table 1
Non-Union Scoring System

		Score ^a	Max. score
The 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	3
Primary injury - open or closed fracture	Closed	0	
	Open 1° grade	1	
	Open 2-3° A grade	3	
	Open 3° B-C grade	5	5
Number of previous interventions on this bone to procure healing	None	1	
	<2	2	
	<4	3	
	>4	4	4
Invasiveness of previous interventions	Minimally-invasive: Closed surgery (screws, k wires, . . .)	0	
	Internal intra-medullary (nailing)	1	
	Internal extra-medullary	2	
	Any osteosynthesis which includes bone grafting	3	3
Adequacy of primary surgery	Inadequate stability	0	
	Adequate stability	1	1
Weber & Cech group	Hypertrophic	1	
	Oligotrophic	3	
	Atrophic	5	5
Bone alignment	Non-anatomic alignment	0	
	Anatomic alignment	1	1
Bone defect - Gap	0.5-1 cm	2	
	1-3 cm	3	
	>3 cm	5	5
Soft tissues			
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	6
The patient			
ASA Grade	1 or 2	0	
	3 or 4	1	1
Diabetes	No	0	
	Yes - well controlled (HbA1c < 10)	1	
	Yes - poorly controlled (HbA1c > 10)	2	2
Blood tests: FBC, ESR, CRP	FBC: WCC >12	1	
	ESR >20	1	
	CRP >20	1	3
Clinical infection status	Clean	0	
	Previously infected or suspicion of infection	1	
	Septic	4	4
Drugs	Steroids	1	
	NSAIDs	1	2
Smoking status	No	0	
	Yes	5	5

^a Higher score implies more difficult to procure union.

specialised treatments should be sought. Finally, patients with scores above 75 may be candidates for consideration for primary amputation.

Discussion

The weighting and the choice of factors to be included in this table was based on the experience of the senior authors (GC, MP and PG) who have tertiary referral non-union practices, together with consultations of the senior authors with similarly-interested colleagues at seminars and congresses. We feel we have included all factors which may have an impact on the complexity and difficulty of treatment of any fracture non-union.

The adequacy of primary surgery is clearly an important factor and well recognised to be a common source of failure of primary surgery.^{26,27} The effect of this factor on the likely success of later treatments is more difficult to assess, but we hope that some trends will emerge from this data being collected.

The size of fracture gap and the presence of bone loss in primary fracture surgery are also well known to be a risk factor for delayed and non-union of fractures.¹ Whether this is also true for non-union surgery, we cannot be sure. However, it seems likely that this is the case and so we have included it in our system.

We have also included factors for which there is very little evidence of predictive power in non-union surgery, such as number of previous interventions, presence of osteoporosis, soft tissue cover and ASA grade. Because it seemed likely to us that these factors may be influential on the outcome, we have included them.

There is a substantial amount of evidence to support the inclusion of smoking, steroids and nonsteroidal anti-inflammatory drugs (NSAIDs) as predictors of nonunion in fracture healing.^{1,18} It is intuitive to assume that they are also predictors of failure of non-union surgery, though this has not been proven to our knowledge.

Similarly, open fractures are at high risk of non-union, and we have included this as a risk factor for non-union surgery because the causes of failure of fracture repair in open fractures (soft tissue stripping and contamination) are assumed to be present in the non-united fracture too.^{11,14} Diabetes seems to have an adverse effect on fracture repair, and in the absence of any evidence on whether diabetes adversely influences non-union surgery, we have included it in the scoring system too.¹

We hope that the inclusion of known risk factors for adverse primary fracture healing in the scoring

system will allow us to collect and analyse the effect size of these factors, perhaps for the first time, for secondary fracture repair in non-union surgery.

We are aware that this system has not yet been validated. The system will be subjected to clinical validation and is currently being used to gather data for the purpose of validation. Single centres are not exposed to sufficient numbers of cases to derive meaningful subgroups from which validation can be conducted. We therefore propose that this system is adopted in as many centres as possible and the results will be collated centrally via a central data collection registry. There already exists a database for the purpose of collecting outcomes in non-union cases in the form of the BMP User group database established at Leeds (www.bmpusergroup.co.uk). We propose to use this as a data gathering portal using these criteria, with, we hope many centres from around Europe/the world contributing cases. In this way we would hope to gather sufficient information (from thousands of cases) in a relatively short time (1-2 years) to begin to make some useful conclusions and to allow validation of this scoring system.

This scoring system has strengths and weaknesses. In its favour, it is the first attempt to embrace all factors which influence non-union outcomes. It has been constructed with considerable thought and consideration from experienced surgeons, with some supporting evidence from the literature. It will be a very useful tool and help to dissect out features which are, and others which are not, predictors of poor outcome. The weaknesses of this system are in its lack of validation. However, until large experience is gained with a scoring system of any sort, validation cannot be attempted. Because of the heterogeneity of non union cases, and the relative paucity of cases in each centre, we felt that the best approach would be to publish a system so that widespread experience with this tool could be obtained from many centres. Only then can it be validated.

Conclusion

We have proposed a scoring system that we believe will be useful to interested clinicians when assessing a patient with fracture non-union. High scores will suggest that specialist treatments and expert surgery will be required to obtain a good result. Low scores would suggest that good results should be obtained in most cases by competent surgeons using standard treatments. In the future,

we would hope that, through the use of this system, cohorts of patients with nonunions of different complexity will no longer be compared with each other and research results can be stratified appropriately.

Conflict of Interest statement

The authors state that they received nothing of value with regard to this manuscript. There is no conflict of interest.

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