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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
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WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman** (**Кириллица**), ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

EARLY PREDICTORS OF NON-UNION OF DIAPHYSEAL TIBIAL FRACTURES BASED ON SCORING SYSTEMS

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Abstract.

Introduction: The lack of standardization in the assessment of healing potential of diaphyseal tibial fractures in the early stages of treatment leads to late diagnosis of non-union, which requires the development of prognostic diagnostic criteria that take into account possible risk factors. **Objective:** To analyze and evaluate the available scoring systems for predicting union and non-union of diaphyseal tibial fractures. **Methods:** We searched for publications in Scopus (Elsevier), PubMed, Publons, Medline, RSCI, Google, and Google Scholar databases. **Results:** Six systems for predicting the risk of non-union of tibial fractures were analyzed, 4 of which included clinical and surgical risk factors for non-union. The advantage of the scoring systems is the identification of interventional thresholds for early detection of non-union. **Conclusions:** The Radiographic Union Scale for Tibia (RUST), the Tibia FRACTure prediction healING (FRACTING), the Leeds-Genoa Non-Union Index (LEG-NUT), and the Non-Union Scoring System (NUSS) are the most researched and recommended for clinical use. The Non-union Determination Score (NURD) and Tibial Fracture Healing Score (TFHS) systems require further evaluation.

Key words. Diaphyseal fractures, diagnosis of non-union, delayed consolidation, prognostic scoring systems.

Introduction.

The number of fractures is on the rise worldwide. In 2019, this number reached 178 million cases, an increase of 33.3% compared to 1990 [1]. According to the Swedish Fracture Registry, the overall incidence of tibial fractures is 51.7 cases per 100,000 per year, of which 15.7 cases per 100,000 per year are tibial diaphyseal fractures (TDF), of which 17.7% are open fractures [2]. At the same time, more than 450 million fracture patients require re-treatment each year due to acute and chronic complications.

Non-unions are a serious complication of long bone fractures, with an incidence of 5 to 10% [3]. In the United States, approximately 6 million fractures are reported each year, of which 1.9% to 15% are non-unions [4]. Complications of TDF, such as malunion, delayed fragment consolidation and non-union, have been reported to occur in 4–16% of cases [5,6]. These complications are associated with significant socio-economic aspects: healthcare costs, reduced quality of life of patients due to prolonged treatment and unplanned surgical interventions [7].

Currently, surgeons and orthopedic surgeons do not have a universally accepted definition and timing of 'non-union' of a fracture; it remains controversial and varies widely [8,9]. Based on a systematic review of 148 literature sources, the authors found that only 50% of studies provided a definition of non-union, making it difficult to standardize the approach to diagnosis and treatment [9].

The FDA defined 'non-union' in 1998 as “...established when a minimum of nine months has elapsed since injury and the fracture shows no visible progressive signs of healing for three months” [10]. However, insufficiently long intervals after initial fracture fixation do not allow early prediction of the development of non-union. In addition, this basic definition considers only the time interval and does not take into account clinical and objective radiological criteria of fracture healing, does not take into account the peculiarities of bone callus formation and its relationship with bone fragments, multiple fractures, large bone defects, infection with bone loss, which pose a risk of non-union much earlier than 9 months [9].

In a study based on a survey of surgeons and orthopedic surgeons, 73% of respondents stated that there was a lack of standardization in the definition of delayed consolidation and 55% felt that there was a lack of adequate definition of fracture non-union, while 88% of specialists confirmed that the diagnosis of delayed consolidation and non-union should be made in a comprehensive manner, taking into account well-defined temporal, radiological and clinical criteria [11]. A challenge in clinical practice is the assessment of fracture healing potential early in treatment, which often leads to a late diagnosis of non-union [12]. Approaches to the diagnosis and management of non-union and delayed consolidation fractures continue to evolve. To date, prognostic diagnostic systems based on scoring have been developed, some of which consider treatment options.

The aim of this review is to analyze and evaluate the available scoring systems for the prediction of fracture union and non-union in diaphyseal tibial fractures.

Methodology.

Publications were searched in Scopus (Elsevier), PubMed, Publons, Medline, RINC, Google and Google Scholar databases. We used the following key words: non-union of long bone fractures, delayed union, scoring systems to assess fracture union and non-union. The search depth was 15 years.

Prognostic systems for assessing fracture union and non-union in scores: The Radiographic Union Scale for Tibia (RUST) has been an important tool for predicting fracture healing in TDF, with scores used to assess fracture healing [13]. The search for early predictors of fracture non-union has led to the development of other scoring systems for the assessment of TDF: The Non-Union Determination Score (NURD) [14,15], The tibia FRACTure prediction healING (FRACTING) [16], The Leeds-Genoa Non-Union Index (LEG-NUT [17], The

Tibial Fracture Healing Score (TFHS) [18]. The Non-Union Scoring System (NUSS) [19], based on patient-specific, clinical and surgical risk factors.

The radiological assessment of tibial fracture healing (RUST): was developed by specialists at the University of Toronto (Canada) and its specific feature is the scoring of 4 regions of the cortex: lateral, medial, anterior and posterior [13]. Each tibial cortical layer is scored from 1 to 3 depending on the degree of fusion, with a minimum score of 4 (definitely not healed) and a maximum score of 12 (completely healed) (Table 1) [13]. If a fracture does not heal, there is no clinical or radiological evidence of healing requiring reoperation, and delayed fracture healing is defined as fewer than three bridging calluses connecting the cortical layers 6 months after injury [20]. It has been clarified that a fracture with a callus and a line or crack in the callus is worth 2 points, whereas a bridging callus without a crack is worth 3 points [21].

***Table 1.** Radiographic assessment (RUST) of tibial diaphyseal fracture fusion in each of the 4 cortical regions [13].*

Cortex score (lateral, medial, anterior and posterior), points	Bone callus	Fracture line
1	None	Visible
2	Present	Visible
3	Present	No fracture line present

Validation of the RUST system was performed by traumatologists, orthopedists and resident trainees on radiographs of patients with TDF using the intraclass correlation coefficient (ICC), and high levels of agreement were achieved: 0.86, 0.83 and 0.81 [13]. RUST scores ranged from 4 to 12 with a mean score of (8.3±2.2) (median 8). High concordance scores have also been reported by radiologists and orthopedic surgeons [22-24]. The high intraclass correlation coefficient indicates the strength of this system.

Studies have used the RUST to define fracture union, delayed consolidation and non-union. A follow-up study showed that the change in the RUST was greatest between 8 and 12 weeks after surgery (RUST >8), and then the RUST values continued to increase, with RUST ≥10 at 17-20 weeks being considered fracture healing [23]. In another study, the mean radiographic time for TDF fracture healing at RUST >10 was 16.4 weeks [20], with consolidation of fragments in 3 cortical regions [14,15,20,25]. Overall, the mean time to healing in the studies is 20.4 weeks for segmental TDFs fractures and 21.2 weeks for splinter fractures. In some studies, TDF were found to heal at RUST=9 points [14,26]. Therefore, according to different studies, RUST=9 points or >10 points are considered as an indicator of fracture healing.

In a study by the authors of the developed scale [60], RUST < 3 points had a sensitivity of 96% and a specificity of 90% in predicting the need for additional surgery due to non-union, with positive and negative predictive values of 75% and 99%, respectively. Most studies consider RUST < 6 points as the intervention threshold for predicting non-union [7,20,27]. At 14 to 27 weeks, RUST <6 was statistically significant in differentiating non-union from delayed fragment consolidation [23]. At 6 weeks after TDF with intramedullary nailing, a sensitivity of 75% and a specificity of 75% were found for RUST < 6 in assessing non-union, with aseptic non-union observed in 72.3% of fractures [20].

Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures (SPRINT) and the Fluid Lavage of Open Wounds (FLOW) trails in patients with TDF after fracture fixation with intramedullary nails. In a multivariate logistic regression model examining risk factors such as tibial fracture type, gap size, and RUST=4 at 3 months, an open fracture was associated with a 5.5-fold increase in the odds of non-union, and RUST=5 or 6 was associated with a 7.7-fold increase in the odds of non-union. An open fracture was associated with a 15.5-fold increase in the odds of non-union, and a score of RUST=5 or 6 was associated with a 5.7-fold increase in the odds of non-union at one year compared with a RUST score ≥7 [28]. Based on a retrospective meta-analysis and case-control studies, a RUST score <6 at 3 months post-fracture was associated with a 7.12-fold increase in the odds of non-union after intramedullary fixation [27]. The meta-analysis also showed that RUST <6 at 3 months post fracture can be considered an interventional threshold associated with a high risk of non-union. In the delayed consolidation group with RUST <10 points at 6 months after fracture, the median time to healing was 32.3 weeks [20]. Another study also found that patients with fractures with RUST <10 points were classified as delayed consolidation at 25 weeks and achieved healing in a mean of 31 (median 29) weeks [23].

The diagnostic value in tibial metadiaphyseal fractures has been improved by the modification of the RUST to the mRUST [29,30]. In addition to the position's characteristic of the RUST, the mRUST introduced the indicators 'visible bridging but fracture line visible' (RUST position 3, 3 points retained) and a new position 4 - absence of remodeling (Invisible Remodeled) and fracture line, where a score of 4 is assigned. According to the mRUST, a minimum total score of 4 indicates a fracture that has not healed and a maximum score of 16 indicates complete fracture healing [30]. In a comparative ROC analysis of mRUST and RUST by area under the ROC curve (AUC), the rates were higher for mRUST (0.986 vs. 0.889) when assessing TDF in pediatric patients [31,32]. Furthermore, mRUST ≥12 points and RUST ≥9 points were identified as predictors of union, whereas mRUST ≤7 points and RUST <9 points were considered predictors of delayed fusion. The authors noted that when radiologists and orthopedic surgeons were assessed using the ICC, moderate agreement was found for RUST and mRUST scores, with slightly increased rates of delayed fusion. Although the RUST scale was developed for TDF in intramedullary nail fixation, RUST and mRUST have been successfully used to assess fracture healing in different anatomical regions and fixation methods, fracture types and after osteotomy [30,33,34-39].

The validation and effectiveness of the RUST scale has led to its widespread use in clinical practice [20,21,26,27,40,41]. Based on literature data, intervention thresholds have been proposed: for fracture non-union <6 points, for delayed consolidation <9 points, and for fracture union >10 points. In addition to positive predictive value, the RUST has some limitations due to the fact that the risk of non-union cannot be predicted earlier than 3 months. A weakness of the RUST scale is that the assessment of the fracture line "visible (yes) or not" after the formation of a bridge-like bone callus has a certain bifurcation [30].

However, although RUST enhances the clinician's ability to assess the degree of TDF consolidation, it may be a significant addition to systems that take into account important risk factors for non-union: infection, chronic disease, surgical features, etc. [17,20,40,42].

The NURD scoring system: for predicting non-union of the TDF after intramedullary nail fixation was developed in the USA by specialists from the Universities of Minnesota and Maryland based on a retrospective cohort study [14,15]. The NURD system includes a scoring scale with 6 clinical and 3 radiological parameters (Table 2) and can be effective in analyzing the risk of fragment non-union immediately after surgery or at staging [43]. The authors of the developed the NURD system presented a scale for predicting non-union. According to the scale, the probability of non-union is 2% for 0 to 5 points, 22% for 6 to 8 points, 42% for 9 to 11 points, and >12 points increase the risk of non-union by 61%. A NURD score ≥9 points are recommended as the intervention threshold for fracture non-union [14]. In another study, when comparing the rates with the empirical incidence of non-union, it was found that except for 0-5 points (3.8%), a lower rate of non-union was found between 6-8 points with 9.3%, between 9-11 points with up to 14.3%, and above 12 points with 16.7% [44]. Based on this study, it was concluded that the NURD system does not provide an intervention thresholds, i.e. it represents a range of probabilities [44]. However, other studies have demonstrated and recommended NURD ≥ 9 points as a threshold for non-union [8,43].

The validity of the NURD system was examined by comparing the results of a SPRINT clinical trial of patients who had undergone intramedullary nail fixation of a fracture and the resulting non-unions. In the initial comparative analysis, the NURD score was shown to have a significantly worse discrimination score than the SPRINT data (0.61 vs. 0.85, $p < 0.01$). However, in a more detailed analysis, fractures in patients in the SPRINT trial had less heterogeneity as assessed by the standard deviation of the linear predictors (NURD 1.4 vs. SPRINT 0.4). After the authors corrected for fracture homogeneity, the NURD score showed the same strong discrimination with the SPRINT data (0.81 vs. 0.85, $p = 0.17$) [46]. The authors concluded that the susceptibility of the NURD was reliable; however, in our opinion, the heterogeneity of fractures in real practice may affect the reliability of the assessment in a given patient. In addition, the weakness of the developed system was the lack of an infection indicator and the fact that the validity of the system was evaluated in a retrospective study.

To improve accuracy, the authors of the developed system added the RUST scores to the NURD clinical fusion prediction tool and took infection into account, allowing a more accurate assessment by 6 weeks post-operatively [15], although this is early for infection prediction. When the RUST and the NURD scores were compared, RUST ≥10 was shown to accurately assess fracture healing independently of the NURD score. However, an additional the NURD score is important in the intermediate RUST score group (6-9 points), with 25% of patients with a the NURD score ≥7 having a non-union. In the group with a low RUST score <6 and the NURD score ≥7 or the presence of infection, 69% of patients had non-union. It was concluded that infection, RUST and NURD scores had a statistically significant association with non-union (odds ratio > or < 1.0; $p < 0.01$), with a sensitivity of 82% and specificity of 82% [40].

Assessing the risk of non-union using this system, but with additional assessment of reliability testing and biomechanical validity, will provide surgeons and orthopedic surgeons with an improved ability to predict non-union and assist in patient management [47].

Due to the ambiguous approach to existing versions of NURD, improvements by the authors of this model are ongoing. A new version of the NURD 2.0 has been created in which the risk score for determining non-union has been expanded compared to previous models by adding 6- and 12-week RUST scores and introducing infection and smoking scores [48]. Using the NURD 2.0, it is possible to predict TDF non-union immediately after surgery or at any time within the first 3 months. This model represents a significant improvement over previous models and, according to the authors, allows surgeons to make a timely decision about the need for early surgical intervention. However, the NURD 2.0 has not been validated in other studies.

The FRACTING assessment system: was developed by L. Massari and a group of specialists (42 people, 41 clinics of orthopedics and traumatology) in Italy in 2018 [16]. The basis for the development of the FRACTING system was the previously created prognostic system ARRCO (Algoritmo Rischio Ritardo Consolidazione Ossea) for fracture assessment

Table 2. *Parameters used to calculate the NURD scores (adapted from [14]).*

Clinical parameters (in points)							
Fracture Exposure	Compartment syndrome	Flap coverage requirement 3 % of cortical contact	Male	ASA assessment of the patient's physical condition			Chronic disease
				ASA 1	ASA 2	ASA 3–4	
2	4	5	1	1	2	3	3

Radiological parameters (in points)					
Low-energy fracture **	Spiral Fracture **	% of cortical contact			
		100%	75%	50%	25%
1	2	0	1	2	3

Note: **ASA is the American Society of Anesthesiologists [45]; **One point is deducted for spiral fractures and low energy trauma.*

Table 3. *Parameters used for the FRACTING scores calculation [16].*

Parameters	Additional parameters	Points*	Parameters	Points*
Age increase	18–45 46–60 >60	1 2 3	Bone diastasis, >2mm	1
Malnutrition		1	Length of surgery, >120 minutes	1
Diabetes		1	Fracture of tibia alone	1
Smoking		1	Loss of bone substance	1
Use of NSAIDs**		1	Bone graft	1
Fracture exposure severity	Closed Open grade Open skin < 5 cm Open skin > 5 cm	1 2 3 4	Plate + diastasis	0,5
Location: metaphysis or epiphysis		1	Angular stability plat	0,5
Synthesis device	Nail 1 Plate 2 External fixation	1 2 3	Plate + plaster cast	-0,5
Unstable Yes		1	Blood hemoglobin before treatment < 10 g/dl	1
Misalignment > 5		1	Blood hemoglobin after treatment < 10 g/dl	1

NOTE: ** if the parameter is present, the corresponding score will be given, if it is absent - 0. **NSAIDs: nonsteroidal anti-inflammatory drugs.*

in points based on retrospective analysis [49]. The improved the FRACTING system, based on a prospective study, provides the most complete representation of clinical and radiological positions and the impact of surgical treatment (Table 3).

The FRACTING system includes an important risk factor such as smoking, which increases the relative risk of non-union (odds ratio, OR 2.42) and delayed consolidation of diaphyseal fractures (OR 1.78) [20,50]. Information about the risk of non-union can be provided to the patient to address this modifiable risk factor.

Administration of non-steroidal anti-inflammatory drugs (NSAIDs) <90 days after fracture fixation is associated with non-union of TDF (OR 1.42) [51]. Non-union was observed in 5.18% and 7.79% of patients when NSAIDs were prescribed acutely and chronically [52]. The risk of non-union was higher in patients prescribed selective COX-2 inhibitors after fracture (OR 1.84), but not in patients prescribed non-selective NSAIDs (OR 1.07) [53]. However, if we consider NSAIDs in the context of their importance in relieving pain and inflammation, the practice guidelines of the Eastern Association of Surgeons and Traumatologists and the Association for Orthopedic Traumatology state that prescribing NSAIDs to patients after fractures (effect on inflammation and pain) is superior to potential risk factors for fracture non-union [54]. In all likelihood, the different assessment of the effect of NSAIDs on fracture healing has influenced the neglect of this indicator in the development of other prognostic systems.

Diabetes is a major risk factor with a 1.6 to 2.0 fold increase in the risk of non-union [40,50] therefore, its inclusion in the system improves the accuracy of the assessment.

The validity of the FRACTING system has been demonstrated by its developers in the evaluation of TDF fracture healing in a prospective, multicenter, observational study in 41 Italian orthopaedic and trauma centers [16]. It was based on the analysis of 363 tibial fractures of different types (41-A and B, 42-A and C, 43-A and B, according to the AO classification). It was found that in 12% of patients with a score ≤ 7, healing lasted more than 6 months compared to 43% of patients with a score > 7. ROC analysis (AUC = 0.823) showed high reliability of the score when dividing patients into groups before 6 and after 6 months after surgical treatment. In clinical practice, an effective threshold for the assessment of delayed consolidation and non-union is a score >7, with a sensitivity of 63%, specificity of 81%, and positive predictive value of 53%, indicating fracture healing in more than 6 months. In addition, the authors presented data on the sensitivity, specificity and positive predictive value of the FRACTING system from 3 to 12 points. For example, at a score of 7, the sensitivity of the method was 80%, the specificity was 65%, and the prognostic value for fracture healing was 43% [16].

The FRACTING scale can predict fracture healing time and identify patients at risk of non-union at six-time intervals: immediately after surgery, ≤ 3 months, 4 months, 5 months, 6 months and > 6 months [43]. We found that the mean the FRACTING score (7.3±2.5) was positively correlated with the number of days to healing r = 0.63 (p < 0.0001).

Thus, the strength of FRACTING is its evaluation in retrospective and prospective studies, which improves the accuracy of predicting nonunion, and its ease of use at any stage after surgery. Patient-related risk factors have been introduced into the system. The assessment of anemia in the patient is important, as anemia is known to reduce bone regeneration. The FRACTING has a proven interventional threshold for non-union (>7 points) and can be used to predict and select patients for fracture healing stimulation, such as the use of growth factors, cell therapy, drugs that stimulate or optimize reparative osteogenesis, and physical factors that influence the reduction of the risk of non-union [16,55]. The system takes into account different options for fracture stabilization. The weakness of FRACTING is the presence of items such as malnutrition, instability and bone loss, which can be interpreted differently, the absence of an infection indicator, and the unspecific representation of diastasis (> 2 mm).

The LEG-NUI Non-union Index: developed by E. Santolini et al. in 2020, is based on the evaluation of tibial and femoral diaphyseal fractures (100 non-unions and 100 control patients) [17]. It is a clinical tool that includes eight risk factors, 4 clinical and 4 radiological, to predict fracture fusion or non-union (Table 4). If a patient has a score <5, fracture fusion is predicted; however, if the score is ≥5, the risk of non-union is high [17]. The LEG-NUI scale includes an index of infection as an important risk factor for non-union. The effectiveness of the LEG-NUI system is increased if the calculation is performed at 12 weeks after surgery, as infection development and changes in the indices are possible during this period.

Table 4. *Parameters used to calculate the LEG-NUI score [17].*

Indicators	Points	
	Yes	No
Site of fracture—tibia	1	0
Soft tissue damage (internal degloving or open fracture)	1	0
Type of fracture (wedge or comminuted)	1	0
Displacement—>75% of shaft width	1	0
Method of reduction—open	1	0
Post-surgical fracture gap (>4 mm)	1	0
Mechanical stability—not optimum	1	0
Infection (superficial or deep)	1	0

The validity of the LEG-NUI prediction model was demonstrated. With an optimal intervention threshold of ≥5 points using ROC analysis (AUC 0.93), the sensitivity of the method was 86% and the specificity was 87%. The advantage of the LEG-NUI is that it can be used with different methods of diaphyseal fracture fixation [17].

The LEG-NUI scale has also been validated in a study of 319 open and 77 closed TDF [44]. Fracture non-union was noted in 61 patients (6.7%). The rates of fracture non-union for each score were tabulated by the author, with the highest percentages for scores greater than 5 (20%) and up to 8 (40%). The sensitivity of the method was 86.0%, which is in line with data from the system developers [17], but the specificity was found to be much lower (49.3% versus 87%). The low specificity obtained by the author [44] may be due to the fact that the LEG-NUI was validated by the developers for femoral and tibial fractures, which may have influenced the assessment of specificity when analyzing TDF only. In addition, a positive predictive value of 18.6% and a negative predictive value of 96.3% were evaluated [44]. The LEG-NUI system has been well evaluated in studies [8,14].

Thus, the strength of the LEG-NUI system is the clear definition of its 8 indicators, including the infection indicator. However, the absence of the smoking indicator can be considered a weakness of this system.

For the clinician, a version of the LEG-NUI scale score (https:// apps. apple.com/ gb/ app/ leg- nui/ id150 42081 100) may be convenient, but it is currently only available in the itunes store.

The TFHS system: was developed in 2020 by specialists at the University of Virginia (USA) to identify patients at high risk of non-union of TDF (OTA: 41A, 42A-C and 43-A) [18]. This system has advantages over the standard conventional clinical and radiological examination of patients treated with intramedullary osteosynthesis. The TFHS scores are based on 3 clinical parameters that are evaluated in a single score (Table 5). A prognostic assessment of the risk of non-union can be made during routine postoperative visits.

Table 5. *Parameters used to calculate TFHS scores [18].*

Indicators	Points
Clinical parameters	
Pain. Patient complaints: - pain (none/mild/decreased - no change/increased	 1 0
Function - minimal limp/able to perform a single leg stance - significant limp/unable to perform single leg stance	 1 0
Patient examination: - no/minimal pain with manipulation - pain on manipulation	 1 0
Radiological parameter	
Adjusted Radiographic Union Scale in Tibial fractures (aRUST) [13]	

The authors showed that TFHS score <3 at 12 weeks predicts the risk of fracture non-union and the need for additional surgery with high sensitivity (96%) and specificity (90%). At 3 months after surgery, RUST scores (1 to 3) are also entered into the system [18]. At this time, the sum of the three clinical TFHS scores <2 points and RUST score ≤5 points indicate the risk of non-union. TFHS score <3 points combined with RUST score of 6 or 7 points is considered by the authors to be reliable for identifying patients who require treatment.

The strength of this system is the combination of clinical and radiologic indicators as a weakness of the TFHS system, we can consider the position including "patient examination", which has an element of subjectivity. In addition, it has only been evaluated in a retrospective study and is only shown in patients with intramedullary fixation. Due to its recent development, this system has not been well validated in the nvestigations. Only one study is presented in a comparative analysis of the TFHS with other scoring systems (see below) [8].

Comparative analysis of developed systems for the assessment of fracture union and non-union: In a comparative study of 15 patients with TDF, four available systems were evaluated: LEG-NUI, NURD, FRACTING and TFHS [8]. The following thresholds were used in the assessment of non-union to calculate positive and negative predictive values: FRACTING ≥7 and NURD ≥9 in the immediate postoperative period, and LEG-NUI systems ≥5 and TFHS <3 at 12 weeks after surgery. The positive predictive values for the development of non-union were 80% for FRACTING, 100% for LEG-NUI and 40% for NURD, and the negative predictive values were 60, 90 and 90% respectively. In retrospective analyses, it was not possible to calculate a reliable TFHS accuracy. The authors concluded that LEG-NUI had the best combination of positive and negative predictive values for the early detection of non-union [8].

In another multicenter study, a comparative analysis of three systems FRACTING, NURD and LEG-NUI was performed to predict the outcome of fusion and non-union of TDF, taking into account the age and gender of the patients and the fracture characteristics when using intramedullary nail fixation [43]. Based on this study, the authors used thresholds of FRACTING ≥ 8 and NURD ≥ 9 in the immediate postoperative period. LEG-

NUI scores ≥ 5 were calculated 12 weeks after fracture fixation. The sensitivity values of FRACTING, NURD, LEG-NUI were 63.41%, 14.63% and 58.54 respectively, the specificity values were 86.52%, 96.63% and 91.07% respectively, the positive predictive values were only estimated for FRACTING 68.42% and LEG-NUI 75.31%. The negative predictive values for FRACTING, NURD, LEG-NUI were 83.7%, 70%, and 83.27%, and the F-test (a measure of prognostic performance) was 67%, 18%, and 58.06%, respectively. Based on the data, the authors concluded that FRACTING had the best ability to identify patients at risk of non-union according to the highest sensitivity and F-test scores. NURD had the lowest sensitivity. A study by K. O'Halloran et al. also showed a low diagnostic accuracy of NURD, while FRACTING and LEG-NUI scores were similar (79.2%) [14]. The FRACTING system showed a prognostic value (83.7%) and specificity (86.5%), whereas the LEG-NUI score showed a better negative predictive value (85.3%) and sensitivity (68.3%). These two systems are recommended to be used in clinical practice to select the surgical approach and to guide postoperative therapy [14].

A comparative analysis of LEG-NUI and NURD also showed better performance of LEG-NUI in terms of discrimination score (c=0.802 (0.709 -0.895), p = < 0.001 vs. c=0.693 (0.592 - 0.793), p < 0.001, 95% CI [44]). A score greater than 0.7 indicates a good model fit and a score greater than 0.8 indicates a strong model fit.

No comparative analysis of the updated version of NURD 2.0 [48] with other prognostic systems was found in the available literature.

NUSS fracture non-union scoring system: The NUSS scoring system was developed for incipient non-unions [19,56] and differs from other systems presented above in that it combines predictors and features of non-union in the early postoperative period (humerus, femur and tibia) and suggests management tactics for patients [57-59]. Taking into account previously developed prognostic systems, NUSS is the first multi-factorial approach to non-union based on 15 different indicators grouped into 3 blocks: bone status, fracture and surgical characteristics, soft tissue status and patient health, with a total score ranging from 4 to 100 points [56].

Patient-related factors such as chronic disease, smoking, steroid and NSAID use are included as important risk factors for non-union. In addition, the invasiveness of previous procedures, type of non-union, soft tissue status (previous scars, vascularization problems and skin defects, etc.), assessment of the patient's condition according to the ASA scale, etc. (Table 6) [56,58].

The NUSS scale can be used at admission of patients with non-unions, correlates with the clinical complexity of a particular patient, and makes it possible to predict further outcome. On this basis, for the first time, a therapeutic treatment protocol has been created, represented by 4 classes depending on the score, and the effectiveness of treatment options for non-union in each class has been demonstrated (Table 7) [19,57-59].

Studies have shown that the proposed treatment strategy corresponds well with the final treatment ($\chi 2 = 29.963$, 9 degrees of freedom, $p < 0.001$) [57,60].

The results of the validation of the NUSS system by G.M. Calori et al. (300 long bone non-unions) showed that in patients with clinically and radiologically confirmed non-unions after NUSS treatment, 86% of patients had positive results in grade 1, 87% of patients in grade 2 and 82% of patients in grade 3, and the mean time to clinical healing was (8.78 ± 2.04) months, (9.02 ± 1.84) months and (9.53 ± 1.4) months, respectively [56].

In a retrospective study [61] to validate the NUSS system [19], 40 patients were divided into three groups. All class 1 patients treated according to the NUSS guidelines achieved a fracture fusion rate of 97.05%, class 2 patients achieved a fracture fusion rate of 83.67% and in class 3 only 20% of patients achieved fracture fusion. The authors [61] noted that they obtained similar results to the study published by G.M. Calori et al. for patients with scores of 0-25 and 26-50 [19].

Another study also investigated the effectiveness of the NUSS system in treating patients with ununited fractures of the femur, tibia and humerus [58]. In the evaluation of 39 (33.62%) patients with TDF divided into grade 1 and grade 2, 100% fusion was observed in 100% of patients and 16.66% in grade 3. The risk of non-union in untreated patients was 28 times higher than in patients treated according to the NUSS guidelines. The authors believe that using the NUSS as a guideline for diagnosis and treatment planning in patients with non-united fractures can significantly improve the effectiveness of treatment [58].

The strength of the NUSS system is its comprehensive multifaceted consideration of risk factors that have been evidenced in the literature. It is the first classification that takes into account bone and soft tissue status, type of nonunion, fracture and surgical characteristics, and patient and patient-related risk factors. However, the creators of the NUSS system noted that it did not sufficiently reflect the influence of biological factors [19,56].

In a later study, the NUSS scale was successfully used to evaluate different treatment options for non-union of TDF: monotherapy (bone autograft and secure fixation) and polytherapy (biological therapy) [62]. A significantly higher NUSS score (48 vs. 38) and success rate (95% vs. 58%) were found in the polytherapy group of patients compared to the monotherapy group, but in this group, ROC analysis with a high NUSS score showed a high predictive performance (AUC=0.9143), and when the threshold was set (at 48 points), the sensitivity was 100% and the specificity was 70.0%. The NUSS is considered a reliable and clinically valid system for prognostic assessment of fracture healing and proposed treatment options [58,60,62].

Currently, the NUSS system can be considered as the most effective tool for classifying and predicting the complexity of nonunion and on this basis the practitioner can plan the emergency treatment of a patient with TDF and nonunion. The creation of a mobile application based on the risk factors presented in the classification would be of great help to the clinician and could greatly facilitate the use of this system.

Conclusion.

Some of the most important clinical and basic research in traumatology and orthopedics are developments based on the prediction of the risk of fracture non-union. Adequate diagnosis based on a standardized definition of the criteria for fusion,

Table 6. *NUSS scoring system for patients with non-unions [56].*

Condition assessment	**Indicators**	**Score (points)**	**Maximum score***
Bone	Good	0	
	Moderate (e.g. mild osteoporosis)	1	
	P Poor (e.g. severe porosis or bone loss)	2	
	Very poor (necrotic, appears avascular or septic	3	3
Primary injury –open or closed	Closed	0	
	Open 1 grade	1	
	Open 2-3 grade (a)	3	
fracture	Open 3 grade (b–c)	5	5
Number of previous interventions on	None	1	
	<2	2	
	<4	3	
this bone to procure healing	>4	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 graftin	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-anatomical alignment	0	
	Anatomical alignment	1	1
Bone defect (gap)	0,5 -1 cm	2	
	1–3 cm	3	
	>3 cm	5	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	6
The patient			
Physical status of patients according to	1 or 2	0	
*the (ASA)***	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: white blood cell count (WCC) > 12*	1	
	Erythrocyte sedimentation rate (ESR)> 20	1	
	C-reactive protein (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
The sum		50****	50

** The highest score in each group summarizes that it would be difficult to achieve fusion.*
*** ASA – American Society of Anesthesiologists [45].*
****NSAIDs – non-steroidal anti-inflammatory drugs.*
***** Patient's total score is multiplied by two.*

Table 7. *Patient management approaches based on the NUSS scoring system (adapted from [19,57]).*

Distribution of patients by class	NUSS score	Treatment approaches for non-unions
1 class	0–25	Non-union associated with a mechanical problem is amenable to standard treatment - improving fixation stability, possibly by choosing a different system.
2 class	26–50	Correction of fixation, possibly using the same system. In addition, physiotherapy (pulsed electromagnetic field, extracorporeal shock wave therapy) or biotechnology may be used to stimulate regeneration.
3 class	51–75	Creation of mechanical conditions, if necessary - resection of non-unions, autograft may be used. In addition, regenerative therapy methods (growth factors, mesenchymal stromal cells, etc.) are indicated.
4 class	76–100	Depending on the anatomic location of the fracture and the amount of bone loss, amputation, arthrodesis, prosthesis or megaprosthesis implantation may be possible.

delayed consolidation and fracture non-union is necessary to accurately assess the optimal management of patients with TDF and for research purposes. The search for and validation of risk factors has led to the development of the RUST system and other systems that reflect temporal, clinical and radiological parameters in different ways, but which have the advantage of being specifically patient- related factors, allowing prediction of fracture status and timely application of the necessary treatment measures. In most studies in adult patients, a RUST <6 (no bone callus formation) at 3 months after fracture has been confirmed as a predictor of high risk of non-union and is considered a intervention thresholds. The fracture prognostic systems described in this paper, such as LEG-NUI, FRACTING, NUSS, contribute to the risk stratification of non-union. The intervention thresholds of the developed systems have been selected as a result of the studies performed. NUSS additionally offers of management strategy for patients with fracture non-union. Future studies should aim to prospectively validate the developed fracture union – non-union scoring systems to identify their strengths and weaknesses and the management options used.

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РАННИЕ ПРЕДИКТОРЫ НЕСРАЩЕНИЯ ДИАФИЗАРНЫХ ПЕРЕЛОМОВ БОЛЬШЕБЕРЦОВОЙ КОСТИ, ОСНОВАННЫЕ НА БАЛЛЬНЫХ СИСТЕМАХ

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Введение. Отсутствие стандартизации в оценке потенциала заживления диафизарных переломов большеберцовой кости на ранних этапах лечения приводит к поздней диагностике несращения. что требует разработки прогностических критериев диагностики, учитывающих возможные факторы риска. ***Цель:*** проанализировать и оценить имеющиеся балльные системы для прогнозирования сращения и несращения диафизарных переломов большеберцовой кости. **Методология**. Поиск публикаций проводили в базах Scopus (Elsevier), PubMed, Publons, Medline, РИНЦ, Google, Google Scholar. **Результаты**. Проанализировано 6 систем, прогнозирующих риск несращения диафизарных переломов большеберцовой кости в баллах, 4 из которых включали клинические и хирургические факторы риска несращения. Преимуществом балльных систем является определение отрезной точки для раннего выявления несращения. **Заключение**. Из прогностических систем наиболее исследованы и рекомендованы для использования в клинической практике: рентгенологическая шкала оценки сращения большеберцовой кости (RUST), предикторы несращения большеберцовой кости (FRACTING), индекс несращения Leeds-Genoa (LEG-NUT) и система несращения (NUSS), предназначенная для ранней диагностики и разработанной на ее основе тактики лечения. В дополнительной оценке нуждаются системы: шкала определения несращения (NURD) и шкала заживления переломов большеберцовой кости (TFHS).

Ключевые слова: диафизарные переломы, диагностика несращения, замедленная консолидация, прогностические балльные системы.