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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.
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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:

THE ROLE OF 3D MODELING IN THE SURGICAL MANAGEMENT OF HIATAL HERNIAS: A LITERATURE REVIEW

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Abstract.

Introduction: Surgical treatment of hiatal hernia (HH) and concomitant gastroesophageal reflux disease (GERD) remains one of the most complex and controversial areas of modern abdominal surgery. Traditional two-dimensional imaging techniques, such as radiography and conventional computed tomography (CT), are often insufficient for detailed assessment of the complex spatial relationships within the esophagogastric junction. This frequently leads to inaccuracies in preoperative planning and, consequently, to unsatisfactory long-term surgical outcomes. In this context, three-dimensional (3D) modeling based on CT data offers new opportunities for the development of personalized surgical strategies.

Objective: To characterize, based on a comprehensive analysis of the literature, the current state, practical applications, and future directions of 3D modeling technologies in the surgical management of hiatal hernia (HH), including the following aspects: diagnosis of the pathology; preoperative planning of the surgical extent and operative strategy; intraoperative navigation; and evaluation of the effectiveness of surgical treatment.

Materials and Methods: A systematic review was conducted in accordance with the PRISMA guidelines. Publications from 2010 to 2025 were searched and analyzed. The literature search was performed using several scientific databases, including PubMed, Web of Science, Scopus, eLIBRARY, and CyberLeninka. The research methods included analytical review and data synthesis. The inclusion criteria comprised original clinical studies, review articles, and case reports addressing the application of 3D modeling, CT-based anatomical assessment, and virtual and augmented reality technologies in the surgical management of hiatal hernia (HH) and gastroesophageal reflux disease (GERD). Filters were applied to include only studies published in English or Russian and conducted in human subjects. Particular attention was paid to studies reporting clinical effectiveness and practical outcomes associated with the use of these technologies in HH and GERD surgery. The literature search was performed using the following keywords: "reflux esophagitis," "hiatal hernia," "computed tomography," "preoperative planning," "surgical navigation," "3D modeling," and "augmented reality."

Results: The analysis of the obtained data confirms that the implementation of 3D modeling leads to modification of the standard treatment protocol for hiatal hernia (HH). At the diagnostic stage, this technology enables reliable identification of the type and size of the hernia, as well as detailed assessment of anatomical structures that are critical for surgical intervention, including the length of the abdominal esophagus, the degree of separation of the diaphragmatic crura, the presence and extent of esophageal shortening (if present), and specific features of vascular anatomy. These data allow the surgeon to comprehensively evaluate patient-specific anatomical characteristics, determine the optimal surgical approach (laparoscopic, robotic, thoracic, or open), and select the most appropriate type of fundoplication (Chernousov, Nissen, or Toupet technique).

Conclusion: The integration of 3D modeling technologies into routine clinical practice enables comprehensive visualization of anatomical structures, precise measurement of the pathological lesion, and determination of its spatial relationship with adjacent organs and vascular structures. This facilitates accurate planning of the extent and strategy of surgical intervention, minimizes the risk of intraoperative complications, and improves the overall effectiveness of surgical treatment.

Key words. Hiatal hernia, 3D modeling, computed tomography, preoperative planning, reflux esophagitis.

Introduction.

Currently, hiatal hernias (HH) represent the most common benign pathology of the esophagogastric junction. This condition is one of the leading causes of gastroesophageal reflux disease (GERD) and accounts for more than 90% of all diaphragmatic hernias. Despite significant advances in surgical techniques and the transition to minimally invasive approaches, the problem of a high recurrence rate remains relevant, reaching up to 17% of cases, with approximately 9% of patients requiring reoperation [1-3]. The high prevalence of HH determines its considerable clinical significance in surgery: the increasing detection rate of this pathology correlates with a growing number of surgical interventions, as well as with a rising proportion of recurrent hernias. Revisional operations are associated with substantial technical difficulties caused by disruption of anatomical landmarks following previous surgical interventions [4,5].

The history of surgical correction of hiatal hernia (HH) dates back to 1919, when A. Soresi performed the first surgical procedure for this pathology. In the following decades, fundamental contributions to the development of antireflux surgery were made through the research and clinical innovations of Allison, Belsey, Nissen, Toupet, Dor, and Collis, who established the anatomical and physiological foundations of surgical treatment for HH [6,7].

In the 1990s, the introduction of laparoscopic technologies marked a major breakthrough in the surgical treatment of hiatal hernia (HH). Minimally invasive techniques reduced the surgical trauma associated with these procedures and expanded the indications for operative management. However, according to some authors, the quantitative increase in the number of procedures was not accompanied by a comparable qualitative improvement in treatment outcomes. Despite the technological simplification of surgical access, the key anatomical and pathophysiological aspects of HH and reflux esophagitis have remained unchanged.

In contemporary clinical practice, several unresolved issues remain. These include a high recurrence rate (in paraesophageal and large axial hernias, recurrence rates reach 30–60%, often necessitating reoperation); esophageal shortening (this condition frequently remains undiagnosed before surgery, which negatively affects outcomes and may lead to tissue tension, ischemia, slippage or disruption of the fundoplication wrap, and ultimately recurrence); and the choice of fundoplication technique, whether complete (360°) or partial (270° or 180°), which is often based on the surgeon's subjective preference. Another controversial issue is the use of mesh implants. Ongoing debates regarding the feasibility of implant placement (tension-free versus mesh-reinforced repair) for hiatal defect reconstruction have not yet led to the establishment of an optimal approach. Complications associated with mesh migration and erosion have prompted many specialists to avoid their routine use [8-12].

Conventional diagnostic methods, such as contrast radiography and esophagogastroduodenoscopy (EGD), provide a two-dimensional, often static, and largely subjective representation of the complex, three-dimensional, and dynamic anatomy of the esophagogastric junction. Although computed tomography (CT) is inherently a three-dimensional modality, its interpretation is typically performed through analysis of a series of two-dimensional slices. This requires the surgeon to mentally reconstruct a volumetric image, which is prone to errors and dependent on individual experience. At the intersection of unresolved clinical challenges and the limitations of diagnostic techniques, a new paradigm has emerged — digital (personalized) surgery. A central component of this approach is three-dimensional (3D) modeling — a technology for creating interactive, anatomically accurate virtual models of organs and pathological structures based on CT or MRI data. This tool enables detailed preoperative study of patient-specific anatomy, quantitative assessment of parameters previously inaccessible for measurement, and the development of a surgical plan, including the opportunity for virtual rehearsal of the procedure.

Advances in radiological imaging, particularly computed tomography (CT), have made it possible to obtain valuable diagnostic information that can be used to plan the extent of the forthcoming surgical intervention. Modern radiological techniques, especially multislice computed tomography (MSCT), provide detailed anatomical information essential for evidence-based planning of hiatal hernia (HH) surgery. The advantages of a 3D model of the organ of interest in preoperative planning include: detailed study of organ anatomy (the spatial model allows measurement of the pathological lesion, determination of its size, and assessment of its position relative to adjacent organs and vascular structures); selection of the optimal surgical approach (preoperative evaluation of various operative scenarios with calculation of incision trajectories and potential risk to critical structures, which overall shortens operative time and reduces the risk of complications); and visualization of vascular architecture (by integrating the spatial model with an endoscopic camera, the surgeon can observe arterial and venous structures superimposed on the operative field in real time).

This article focuses on the application of 3D modeling in antireflux surgery, examining its advantages and limitations, as well as the potential for tailoring surgical strategies based on patient-specific anatomical characteristics.

Materials and Methods.

Methodology: The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were used as the framework for this systematic review, ensuring methodological rigor and clarity of presentation.

Search Strategy: A comprehensive literature search and analysis were performed using electronic databases, including PubMed/MEDLINE, Web of Science, Scopus, Embase, eLIBRARY, and CyberLeninka, covering publications from January 1, 2010, to December 31, 2025. Unpublished data, organizational websites, and clinical trial registries were not included. The following search terms were used: "reflux esophagitis," "hiatal hernia," "computed tomography," "preoperative planning," "surgical navigation," "3D modeling," and "augmented reality." Filters were applied to include only peer-reviewed publications in English or Russian. Additional relevant articles were identified through manual searches of reference lists in reviews and meta-analyses.

Selection Criteria:

Inclusion criteria were as follows: publications dated from 2010 to 2025; original clinical studies, review articles, case reports, and publications addressing the use of 3D modeling, CT-based anatomy, and virtual or augmented reality technologies in the surgical management of hiatal hernia (HH) and gastroesophageal reflux disease (GERD). Filters were applied to include only peer-reviewed studies published in English or Russian and conducted in human subjects. Particular attention was given to studies reporting clinical effectiveness and practical outcomes of the methods applied in HH and GERD surgery. Only studies containing clinical or validation data were included.

Exclusion criteria included: studies with insufficient or ambiguous methodology, non-peer-reviewed sources, and publications in languages other than English or Russian.

Study Selection Process: the selection of studies was conducted according to a structured procedure designed to minimize bias. Duplicates were removed using a Microsoft Excel spreadsheet containing the following fields: author(s), year, country, chronic condition studied, sample size, study design, type of validation, and diagnostic performance outcomes. Data extraction was performed by two independent reviewers using a standardized form to ensure accuracy. Discrepancies were resolved by consensus, and titles and abstracts were screened for eligibility based on the predefined inclusion and exclusion criteria.

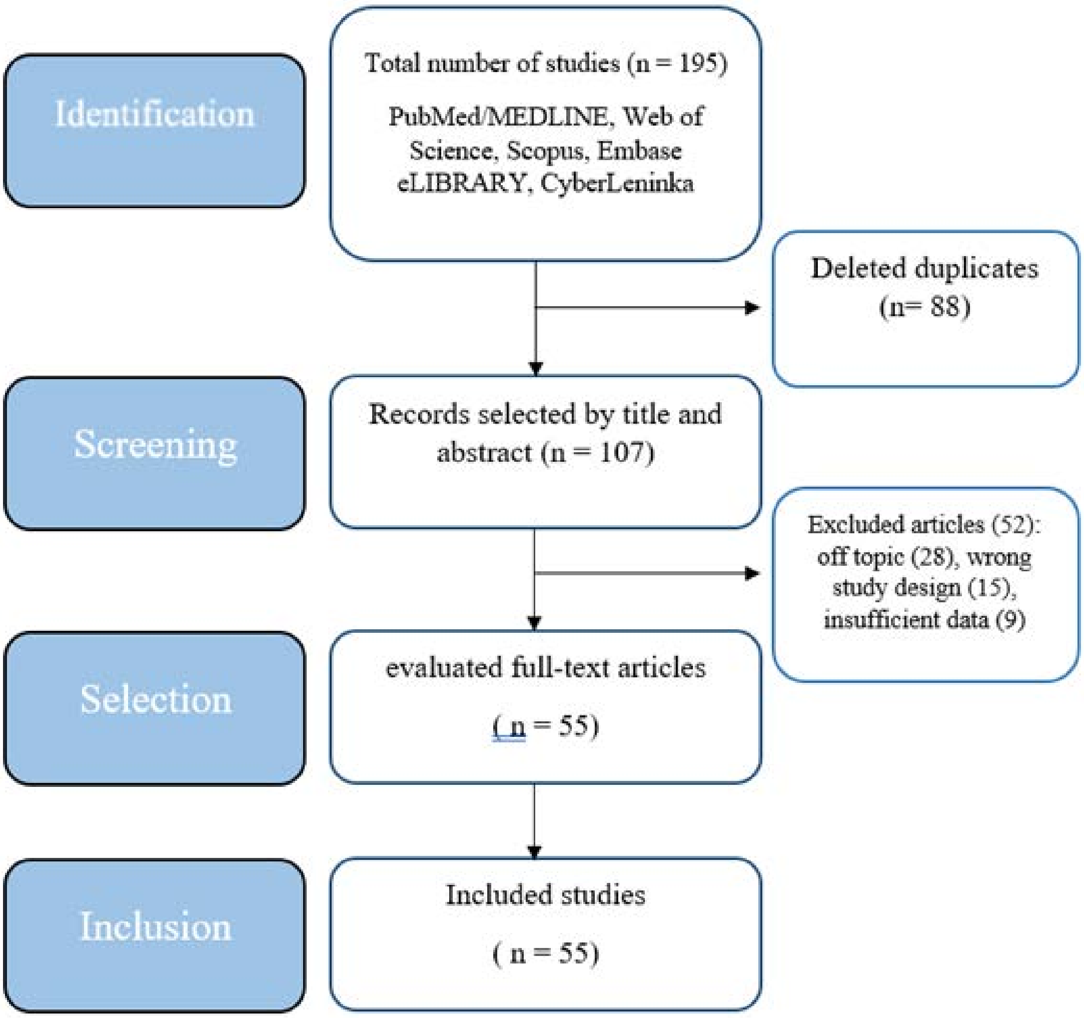


Figure 1. *PRISMA flow diagram.*

Results.

A comprehensive literature search identified 195 publications across various databases. Of these, 103 publications were published between 2010 and 2025, reflecting growing interest in three-dimensional modeling. After removing duplicates, 107 publications remained for preliminary screening. During title and abstract review, 52 studies were excluded due to irrelevance of topic, study design, or type of data and outcome measures, leaving 55 full-text articles for inclusion. No automation tools were used at any stage of the selection process. Ultimately, 55 full-text studies were included in the review (Figure 1).

Review.

The development of the modern classification of hiatal hernias (HH) traces back to the foundational work of N.R. Barrett in the mid-20th century. A definitive systematization was presented in 1967 by D. Scinner and R. Belsey, who identified four primary types of HH, laying the groundwork for subsequent clinical and surgical interpretation of the pathology. For decades, surgical training and medical education relied on two-dimensional schematic illustrations in textbooks. Traditional diagrams depicted simplified "sliding" or "rolling" of the stomach into the thoracic cavity, with idealized representations of the esophagus and diaphragmatic crura. While educationally valuable, these schematics had significant limitations: they were static (lacking dynamic representation of pathological changes), idealized (not reflecting true anatomical variability), two-dimensional (unable to convey volumetric relationships between structures), and simplified (ignoring complex deformations seen in large hernias). As a result, surgeons often encounter intraoperative anatomy that differs substantially from textbook illustrations. For example, in large paraesophageal hernias, there may be a sizable hernial sac causing mediastinal displacement; atrophic and stretched diaphragmatic crura; a shortened and deformed esophagus, often fixed by scar tissue; and rotational changes of the stomach disrupting its natural axis [13].

It is important to recognize that two-dimensional schematics are unable to fully visualize the spatial relationships between organs and critical anatomical structures, such as the descending aorta, celiac trunk, and inferior vena cava. These structures are frequently the source of intraoperative complications, including iatrogenic injury to major vessels and inadvertent trauma to mediastinal organs.

The limitations of conventional visualization highlight the relevance of incorporating three-dimensional (3D) technologies into preoperative planning. A landmark development in 3D

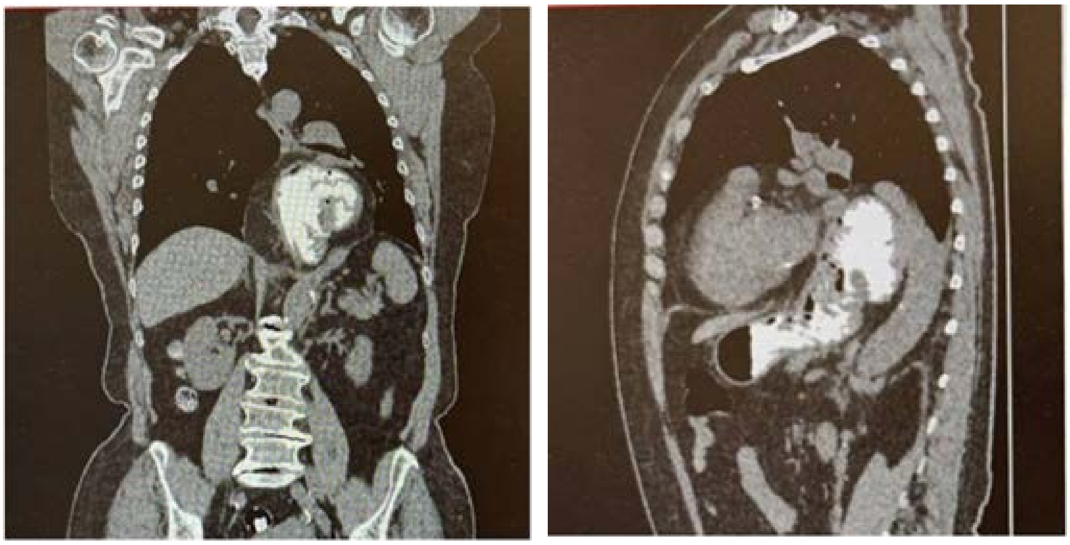


Figure 2 A,B. *Contrast-enhanced MDCT of the thoracic and abdominal organs in a patient with a giant type IV hiatal hernia. (a) Frontal view and (b) Sagittal view. Intravenous and oral contrast agents were administered. The stomach is displaced into the posterior mediastinum. The arrow indicates the approximate level of the diaphragm.*

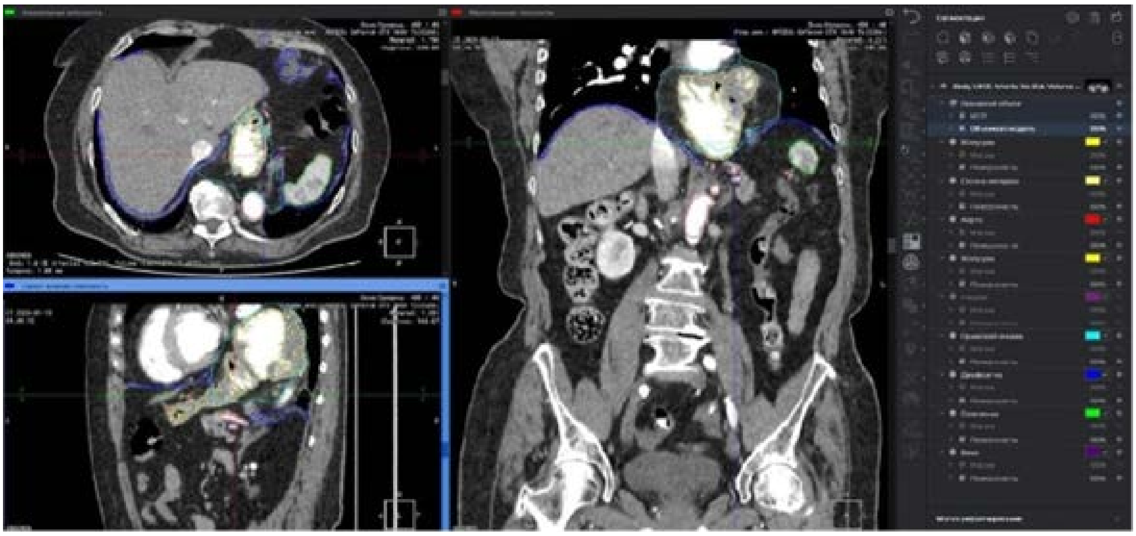
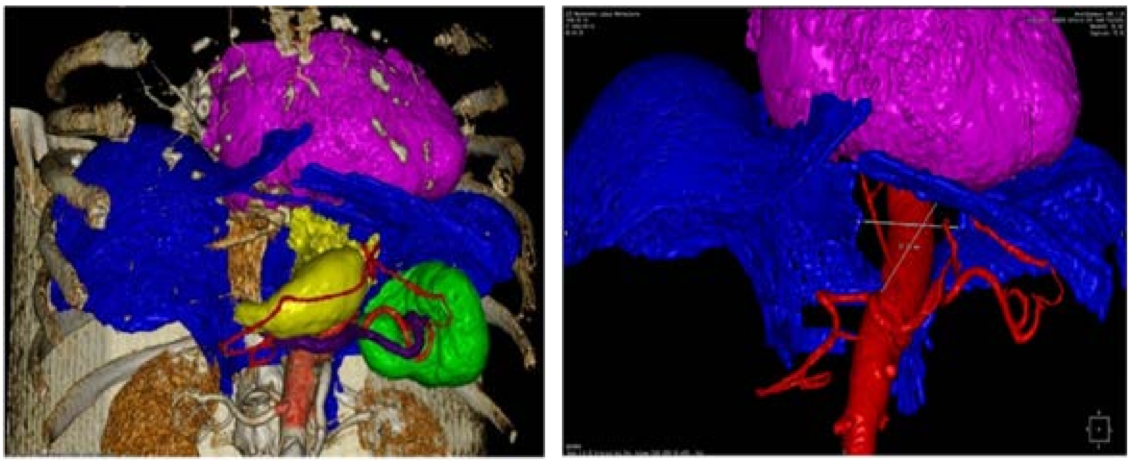


Figure 3. *Segmentation and computer modeling stage. The image shows the segmentation masks used to create the digital model. Different colors represent distinct anatomical structures: blue – diaphragm; green – intrathoracic portion of the stomach (contents of the hernia sac); yellow – intra-abdominal portion of the stomach; red – arterial vasculature (aorta and its branches). This step allows for precise determination of the spatial location of each structure before generating the final 3D model.*



4A *4B*

Figure 4A,B. *3D Modeling. 4a: Pink – stomach above the diaphragm; yellow – stomach below the diaphragm; blue – diaphragm; red – arteries; purple – splenic vein; green – spleen. 4b: Diaphragmatic hiatus. The arrow indicates the diaphragmatic defect, the dimensions of which can be accurately measured using this 3D model.*

visualization was presented by Kavic S.M. et al. (2006), who were the first to apply polygonal surface modeling to create dynamic 3D reconstructions of all four types of hiatal hernias. The study was based on multidetector computed tomography (MDCT) data from real patients. The authors went beyond generating static volumetric images by developing interactive models that could be rotated 360°, allowing anatomical relationships to be examined from any perspective. A key clinical insight from this study was that on two-dimensional slices, the boundary between a large type I sliding hernia and a type III mixed hernia is often indistinct and subjective. In contrast, the 3D model enabled accurate assessment of the gastroesophageal junction and gastric fundus, allowing precise hernia classification. This precision has direct tactical significance, as type III hernias generally require more thorough esophageal mobilization and more secure gastric fixation [14].

Thus, it was demonstrated at an early stage that 3D modeling is not merely a visualization tool, but a means of enhancing diagnostic accuracy, which is a critical prerequisite for successful treatment.

Following the initial successes in reconstructing anatomical structures from two-dimensional CT images, 3D modeling has been actively integrated into surgical practice, both for educational purposes and in the clinical setting. Contemporary studies emphasize the broad potential of this technology, demonstrating positive effects on intraoperative and postoperative outcomes in gastroesophageal surgery when comparing three-dimensional and conventional two-dimensional visualization [15-17]. In the Russian Federation, 3D modeling has been successfully applied for some time in several surgical specialties, particularly urology and hepatobiliary surgery, largely due to the relatively static nature of anatomical structures in these fields. However, in pathologies of the gastroesophageal junction, the situation is different: the dynamic nature of the region and the complexity of its anatomy require specialized approaches. Despite the promise of the method, no large-scale systematic studies on the application of 3D modeling in this area have yet been published in Russia. Although the number of studies examining the benefits of 3D modeling for surgical planning remains limited, available data indicate improvements in clinical outcomes. For example, in urology, the use of 3D technologies has been associated with reduced operative time, decreased blood loss, and shorter hospital stays [18-23].

In modern surgery, 3D reconstruction is utilized for preoperative planning and precise execution of procedures, particularly in complex cases where conventional two-dimensional imaging is insufficiently informative. 3D models can also be employed in training simulators within educational programs for junior surgeons [24-27]. Intraoperative navigation allows for personalization of the anatomy of the gastroesophageal junction and improves orientation during surgery. Several studies have confirmed that preoperative 3D reconstruction contributes to better surgical outcomes and reduces the incidence of postoperative complications [28].

Stages of 3D Modeling in Hiatal Hernia Surgery.

Modern technologies have significantly expanded the potential of 3D visualization. Today, 3D modeling for hiatal hernias (hiatal hernia of the esophageal hiatus, HHEH) represents a multistage process, which includes the following steps:

1. Data acquisition: The foundation of the process is high-resolution multidetector computed tomography (MDCT) of the thoracic and abdominal organs with contrast enhancement. The minimum acceptable resolution is 64 slices (Figure 2).

All figures 2-4 represent original data obtained during the authors' clinical work at Sechenov University and the Additive Technologies Laboratory of Bashkir State Medical University (BashSMU) and comply with all ethical standards.

The scanning phase is critically important:

- Arterial phase — optimal for visualization of vascular structures.
- Delayed phase or oral contrast administration — required for gastric enhancement and detection of sliding hiatal hernias.

Segmentation.

This is the most labor-intensive and critical stage, during which a radiology specialist uses dedicated software (e.g., Materialise Mimics, Synapse 3D, Inobitec Medical Imaging Software for 3D image reconstruction, 3D Slicer image computing platform) to delineate anatomical structures from the CT dataset [29].

The methodology for creating a three-dimensional model includes multiplanar and volumetric reconstruction based on arterial-phase CT data. Segmentation is performed stepwise according to Hounsfield units (HU) using three masking modes: "Threshold" (based on specific HU values), "Interval" (density range), and "Color tables" (for tissues corresponding to the selected palette). The following tables are applied: [WL] high/low intensity, [WL] intensity interval, and CT-Bones + Skin.

Next, contrast and gas within the stomach and intestines are segmented, followed by the arterial vasculature (aorta, left and right gastric arteries, right gastroepiploic artery, splenic artery and vein). Subsequently, the walls of the esophagus and stomach, as well as the spleen, are delineated, and for clarity, the diaphragmatic contour is added. Segmentation surfaces are generated for all masks, enhancing model visualization. The resulting 3D models are later compared with the intraoperative findings, allowing assessment of their accuracy relative to the patient's real anatomy and evaluation of their impact on surgical workflow and the early postoperative period (Figure 3).

Model Generation.

The segmented structures are converted into polygonal meshes, which serve as the basis for creating volumetric, colored, interactive 3D models that allow rotation, scaling, and detailed analysis (Figure 4).

Analysis and Preoperative Planning.

The 3D model enables precise measurements that are either unavailable or poorly informative on 2D slices: exact length of the intra-abdominal esophagus: According to CT-anatomy studies, the normal length ranges from 10 to 53 mm, whereas in hiatal hernia (HH) it can be reduced to zero. Unlike 2D projections, the 3D model allows measurement along the true curvature of the esophagus. Area and geometry of the hiatal defect: Instead of subjective assessment ("large opening"), the model allows precise calculation of the defect's area, determination of its shape

__Table 1.__ Impact of 3D Modeling and Advanced Visualization on Surgical Outcomes.

Surgical result indicator	Quantified benefit of 3D modeling	Source (Reference)	Clinical significance
Operative time	In bariatric surgery, meta-analytic data indicate that preoperative 3D modeling reduces operative time by an average of 23.5 minutes, while in robotic partial nephrectomy, a reduction of 16.2 minutes has been observed. These time savings reflect improved preoperative planning, enhanced intraoperative navigation, and more efficient dissection of critical structures.	Shirk et al., 2019 [23]; Robb et al., 2025 [22]	Reduced anesthesia time, enhanced operating room utilization, potential cost reduction.
Intraoperative blood loss	**Significant reduction in** blood loss (104.6 mL less; standardized mean difference favoring 3D in meta-analysis	Shirk et al., 2019 [23]; Robb et al., 2025 [22]	Reduction in the need for blood transfusions, decreased risk of hemodynamic instability, and a cleaner surgical field.
Length of hospital stay	**Reduction in hospital stay by 1.4 days**	Shirk et al., 2019 [23]	Accelerated recovery, lower healthcare costs, lower risk of in-hospital complications
Complication Rates	**Trend toward reduced intraoperative complications** with improved identification of "invisible" structures, such as aberrant vessels.	Kavic et al., 2006 [14]; Hofstetter et al., 2022 [26]	Improved patient safety, particularly in complex primary and repeat surgeries.
Hiatal hernia recurrence rates	**Potential for reduction** of complications through objective identification of a "short esophagus" and rational patient selection for gastroplasty and cruroplasty.	Chernousov et al., 2011 [8]; Gallyamov et al., 2019 [41]; Fedorov V.I. et al., 2024 [5]	Improved fundoplication function and reduced reoperation rate (9% reoperation rate in the initial data)
Vascular injury avoidance precision	**Objective avoidance of vessels:** 3D models demonstrate arterial variations (splenic and gastric arteries), enabling safe planning of the dissection trajectory.	Sørensen SM et al., 2016 [7]; Robb et al., 2025 [22]; Khorobrykh T.V. et al., 2025 [51]	Essential for the prevention of iatrogenic injuries during gastric fundus and greater curvature mobilization.
Spatial classification accuracy	**Definitive classification** of hiatal hernia types (Type I versus Type III) in cases where 2D slices were ambiguous or subjective.	Kavic et al., 2006 [14]	Simplification of complex anatomical relationships and facilitation of anatomical surgical planning

(round, oval, slit-like), and measurement of the diaphragmatic crura. These parameters are critical for selecting the appropriate repair method (sutures versus mesh implant). Volume of the hernial sac and degree of mediastinal displacement: Enables virtual repositioning of the stomach. The surgeon can "return" the stomach to the abdominal cavity within the model and assess whether esophageal tension occurs—an essential indicator of true esophageal shortening.

Thus, the modern 3D model transforms into a "digital twin" of the patient—a unique, highly accurate anatomical map that can be analysed comprehensively. It serves as the basis for a personalized surgical plan, taking into account individual anatomical features and the specifics of the pathological process. One recognized factor affecting the long-term efficacy of hiatal hernia and GERD surgical correction is secondary esophageal shortening. This anatomic-functional defect remained insufficiently studied for a long time, particularly during the widespread adoption of minimally invasive procedures. By the mid-2000s, however, the scientific community refocused on its role in recurrence and unsatisfactory outcomes of gastroesophageal junction surgery. Reliable preoperative verification of esophageal shortening remains a challenging diagnostic task. Modern instrumental methods (contrast radiography, endoscopy, and manometry) only detect indirect signs: fixation of the gastroesophageal junction above the diaphragm, persistent shortening of the intra-abdominal esophagus, or resistant peptic strictures. These indicators do not provide definitive confirmation of structural alteration, complicating surgical planning [30,31].

The principle of creating a 3D model is based on CT data. The model allows virtual simulation of a reduction maneuver: the stomach can be completely repositioned into its anatomically correct abdominal location and the diaphragmatic crura approximated. After this virtual repositioning, the gastroesophageal junction's position is assessed. If it remains above the diaphragm, and the esophagus appears tortuous, stretched, or cannot reach the intended position without tension, this is a direct indication of esophageal shortening. Using 3D modeling, it is possible to quantitatively measure the "length deficit"—the distance by which the esophagus fails to reach the required level after stomach repositioning.

Obtaining this information preoperatively fundamentally alters the treatment strategy. Instead of discovering the issue intraoperatively—when all efforts are focused on mobilization—the surgeon is already aware that they are dealing with a complex case. This knowledge allows for careful planning of the operative approach, taking into account the identified esophageal shortening, and enables discussion of all risks and potential compromises with the patient during the informed consent process. The patient is thus prepared for a more complex procedure and any specific postoperative limitations. In this way, 3D modeling transforms an intraoperative "complex case" into a planned component of the surgical strategy, increasing the likelihood of a successful outcome and reducing the risk of complications.

Selection of Fundoplication Technique in Hiatal Hernia Surgery: Modern Approaches and the Role of 3D Modeling.

In contemporary surgery for hiatal hernias (HH), the primary fundoplication techniques include: Nissen, Toupet, Dor, and Chernousov procedures. These operations demonstrate high efficacy with relatively low recurrence rates, remaining widely utilized in clinical practice. Nissen fundoplication is considered the "gold standard" in surgical treatment of HH. The technique involves mobilization of the gastric fundus and the upper third of the stomach, wrapping the distal esophagus with the gastric wall to form a complete 360° fundoplication. Many authors note that patients often experience varying degrees of dysphagia in the early postoperative period, usually due to rotation of the esophagus along its axis as the fundus is positioned posteriorly. Reported recurrence rates range from 4% to 10% [32,33]. Toupet has gained popularity for creating a reliable antireflux barrier while minimizing early postoperative dysphagia [34]. The procedure involves esophageal mobilization and suturing the diaphragmatic crura, similar to the Nissen approach, but only partially wraps the esophagus (180°–270°), leaving the anterior-right esophageal surface free to protect the left vagus nerve. The procedure's efficacy averages 95%. Dor was initially proposed as an adjunct to cardiomyotomy (Heller procedure). The technique involves suturing the stomach to the anterior-right esophageal wall and diaphragmatic ligament. Limitations include insufficient prevention of gastric reflux and high recurrence rates (33.3%–100% depending on authors) [35]. This method is appropriate primarily for correcting achalasia with concurrent myotomy. Chernousov, developed by A.F. Chernousov, combines elements of cardia calibration with complete fundoplication. Key steps include full mobilization of the gastric fundus, formation of a cuff without twisting or tensioning the tissues, sequential seromuscular coverage of the lesser curvature, and creation of a symmetrical 4–5 cm cuff with the esophagus positioned between the anterior and posterior gastric walls. The apex is secured with circumferential sutures to prevent slippage. This design ensures the fundoplication cuff remains stable, unlike Nissen or Toupet procedures, which is particularly important in cases of short esophagus. Transient postoperative dysphagia may occur but usually resolves spontaneously within weeks or can be managed with balloon dilation. According to A.F. Chernousov et al., early and long-term outcomes are favorable, with low dysphagia rates (2.4%) and reflux esophagitis (3.5% over 5 years), and satisfactory results observed in 94.4% of patients [6,36-39].

Based on the above, 3D modeling complements traditional approaches by providing critical anatomical context for selecting the optimal type of anti-reflux reconstruction. The key advantages include: assessment of the volume and mobility of the gastric fundus – enabling determination of whether the fundus is involved in the hernia sac. Visualization of vascular anatomy – a 3D model obtained in the arterial contrast phase demonstrates anatomical variations of the splenic vessels and allows planning a safe dissection trajectory, minimizing the risk of vascular injury during mobilization of the gastric fundus and greater curvature. Prediction of vagus nerve course – although the nerves are not directly visible on standard CT, their typical anatomical trajectory along the esophagus can be inferred. The model helps visualize areas at increased risk of nerve injury. Integration of CT and 3D modeling data – provides the most complete anatomical representation, supports informed decisions on the choice of anti-reflux reconstruction technique, enhances the precision of preoperative planning, and reduces intraoperative risks [40,41].

Hiatal Hernia Repair — Is Mesh Necessary?

Returning to the fundamentals of anti-reflux surgery, a key principle is the avoidance of foreign materials in the operative field, as debates regarding the use of mesh implants in hiatal hernia repair continue due to the lack of high-quality evidence confirming their efficacy and long-term safety [42]. Mesh implants may be considered to reinforce the hiatal defect, particularly in cases of large or giant hernias where primary, tension-free closure is challenging. According to B.K. Oelschlager et al. (2011), mesh reinforcement in the treatment of recurrent paraesophageal hernias reduces short-term recurrence rates. Additionally, when it is not possible to reliably approximate atrophic or widely separated diaphragmatic crura, the inlay technique—a tension-free repair with placement of the implant posterior to the esophagus—may be an option, though it carries inherent risks. R.M. Higgins et al. (2017) demonstrated that when reinforcement of the esophageal hiatus is necessary, implant placement is safe and has minimal impact on outcomes of reoperative surgery. It is noteworthy that in repeat operations, many surgeons prefer biologic or biosynthetic meshes, which are partially or fully resorbable over time, providing reinforcement of the hiatal defect while theoretically reducing the long-term risk of mesh erosion.

Despite this, several authors question the safety of mesh placement in the esophageal hiatus, particularly in cases of giant hiatal hernias, due to potential complications such as infection, implant migration, erosion of the esophagus or aorta, and esophageal stenosis or obstruction. In certain fixation techniques, for example the onlay method, the anterior edge of the mesh may contact the esophagus, increasing the risk of dysphagia and other adverse outcomes [43-45].

3D modeling brings objectivity to this discussion by enabling surgical decisions based on the patient's individual anatomy. Key parameters include: defect area: Calculated after virtual approximation of the diaphragmatic crura. "Risk zone" for esophageal contact: Perhaps the most critical parameter. The decision to use a mesh should be made individually, taking into account defect size, tissue quality, coexisting pathologies, and surgeon experience. 3D modeling can serve as a valuable tool to personalize the surgical approach and minimize operative risks.

Role of 3D Modeling in Revision Surgery.

Revision surgery following unsuccessful anti-reflux procedures represents a highly complex intervention, associated with technical difficulties and elevated risk of complications. The primary challenge is complete disruption of normal anatomy due to adhesions in the upper abdominal compartment, often accompanied by replacement of the gastroesophageal junction with fibrotic tissue. Injury to the esophagus, stomach, or spleen during revision procedures is not uncommon. In such cases, 3D modeling based on preoperative CT becomes a crucial tool for planning and risk reduction. It enables the surgeon to: virtually simulate adhesiolysis, identifying the safest planes for scar tissue dissection while visualizing anatomically critical structures obscured by adhesions. Assess the position of displaced organs. In recurrent paraesophageal hernias, the mediastinal contents may include not only the stomach but also small and large intestines and the greater omentum. Contrast-enhanced 3D models provide a clear visualization of the hernia sac contents. Detect deviations, narrowing, or other anatomical anomalies. In cases of extensive intra-abdominal adhesions, a thoracolaparoscopic or even open approach may prove safer, and 3D modeling allows this decision to be made preoperatively. Studies by A. Little et al. demonstrated that patients with fewer prior interventions (e.g., Nissen fundoplication with cruroplasty) show more pronounced clinical improvement compared to those who underwent multiple anti-reflux operations (85% vs. 66%, respectively) [46].

Revision surgery for recurrent and complex hiatal hernias requires a multidisciplinary approach. 3D modeling and virtual planning have become indispensable tools, improving intraoperative navigation, reducing operative risks, and enhancing the likelihood of a successful outcome. Surgeon experience and thorough preoperative diagnostics remain critical components of successful revision surgery.

Preoperative Planning and Virtual Surgery.

Recent advances in digital technology have opened new opportunities for preoperative planning in abdominal surgery. Specialized software platforms, such as Surgical Theatre, VIPER, and 3D Slicer, allow not only the visualization of three-dimensional anatomical models but also interactive surgical planning based on these models. Using these digital tools, the surgeon can virtually mobilize the esophagus, separating it from surrounding tissues and assessing potential dissection challenges; simulate repositioning of the stomach into its anatomically correct location and practice the creation of various types of fundoplication cuffs, selecting the optimal configuration according to the patient's individual anatomical characteristics; perform virtual cruroplasty, bringing together the diaphragmatic crura to evaluate the size and geometry of the hiatal defect after repositioning. This approach allows objective measurement of the defect area, which, when exceeding 5–6 cm^2, may indicate the need for mesh reinforcement of the repair [47].

Research Findings in Related Surgical Fields Studies in cardiac surgery, neurosurgery, and hepatobiliary surgery demonstrate clinically significant benefits of preoperative virtual simulation, including: reduced overall operative time, lower incidence of intraoperative complications, and improved postoperative outcomes. For example, Panchenkov D.N. et al. (2019) reported that virtual 3D modeling in liver surgery allows more precise planning of the resection volume and minimizes the risk of vascular injury. In a randomized clinical trial, J.D. Shirk et al. (2019) showed that using 3D virtual models for planning robot-assisted kidney resection reduced warm ischemia time and decreased complication rates [23,48]. In hiatal hernia surgery (HH), these effects are especially significant in: complex primary interventions, revision procedures after failed anti-reflux surgeries, and cases with pronounced anatomical alterations such as fibrosis or organ displacement [50]. Future research should focus not merely on comparing "with 3D versus without 3D" but on evaluating its impact in patient subgroups stratified by complexity. Literature analysis confirms that the adoption of 3D modeling shifts the paradigm in HH surgery from standardized protocols toward personalized, anatomically informed strategies [51]. Although the body of high-quality evidence specific to HH surgery is still growing, data from related fields—particularly hepatobiliary, urological, and bariatric surgery—provide reliable quantitative benchmarks for the potential benefits of this technology.

For an evidence-based approach, we summarized the quantitative results of key studies assessing the impact of 3D modeling and enhanced visualization on surgical efficiency. Table 1 presents these findings, showing a consistent trend toward improved perioperative outcomes across various areas of abdominal surgery with the use of 3D technologies.

Intraoperative Navigation and Augmented Reality (AR) in Hiatal Hernia Surgery.

The integration of 3D modeling with intraoperative navigation and augmented reality (AR) technologies represents the cutting edge of surgical innovation. The primary goal is to project a preoperatively created 3D model onto the surgical field, aligning the virtual anatomy with the patient's real tissues. This can be achieved through several approaches: monitor-based projection: The 3D model is synchronized in real time with the movements of laparoscopic instruments tracked by sensors. The surgeon observes on a separate screen the position of the instrument tip relative to "invisible" structures in the model (e.g., the splenic artery). Head-mounted AR display (e.g., HoloLens): Surgeons use specialized glasses that overlay semi-transparent 3D contours of anatomical structures onto the actual operative field. This creates a "see-through" effect, allowing visualization of the course of the esophagus within scar tissue, the location of previously placed mesh, and the topography of vascular and neural bundles. The greatest value of AR navigation is demonstrated in revision surgery (during repeat procedures with scarring and distorted anatomy), high-complexity operations (in the presence of vascular anomalies or atypical anatomy), and surgical training, allowing novice surgeons to visualize key structures before actual dissection.

3D Modeling in Surgical Education and Training: New Horizons in Learning.

3D modeling serves not only as a clinical tool but also as a means of education and professional training in hiatal hernia (HH) surgery. Traditional training methods include assisting in surgeries, watching surgical videos, and studying 2D anatomical atlases. These approaches do not provide a full understanding of the spatial relationships between anatomical structures, do not allow interactive practice of surgical maneuvers, and offer only a static representation of normal and pathological anatomy. It is important to distinguish between two primary modalities:

digital 3D models and physical 3D-printed models, as each serves different educational purposes

Digital 3D Models (Virtual Simulation): These interactive models, viewed on screens or through virtual reality (VR) headsets, are primarily used for spatial reasoning. Trainees can rotate, scale, and analyze the model layer by layer, gaining an intuitive understanding of the complex three-dimensional anatomy of the gastroesophageal junction in both normal and pathological states (e.g., various types of hiatal hernia). Junior surgeons can rehearse operative steps on the virtual simulator prior to performing the actual procedure, safely practicing techniques such as mobilization, fundoplication formation, and other critical maneuvers, including management of atypical scenarios. For experienced surgeons, these models offer the opportunity to analyze failed cases and recurrences by visualizing anatomical causes, plan complex revision surgeries based on 3D reconstructions, and refine surgical techniques tailored to individual anatomical features. Experience with such technologies in thoracic surgery demonstrates their high potential. Authors report that AR navigation allows surgeons to visualize anatomical variations in real time, where the incidence of vascular anomalies exceeds 30%, and achieves inter-expert agreement of 98%, significantly higher than standard CT image analysis (85%). These findings indicate that AR technologies enhance the accuracy of identifying complex anatomical structures, which can be directly extrapolated to hiatal hernia surgery [51].

Physical 3D Models Created Using 3D Printers: These are life-size, tangible replicas produced from digital models using additive manufacturing technologies. Their primary educational advantages include: tactile feedback: They provide a realistic sense of touch and tissue handling. In particular, Luigi Marano et al. demonstrated the effectiveness of using 3D-printed models for training in robotic interventions on the gastroesophageal junction. Three-dimensional reconstructions also enhance patient confidence by improving understanding of their diagnosis, thereby facilitating shared decision-making. Thus, 3D modeling fosters an intuitive comprehension of surgical anatomy that is not achievable through traditional sources; provides a safe environment for skills practice; enables personalized training tailored to clinical experience; and strengthens physician–patient partnerships [52-55].

Limitations, Barriers, and Future Directions.

Despite its obvious potential, the integration of 3D modeling into routine surgical practice faces several significant barriers: time constraints. The process of segmentation and creation of a high-quality model by an experienced engineer can be time-consuming. In the context of a busy clinical schedule, this often becomes impractical. Segmentation is extremely labor-intensive. Based on our experience with software such as Materialise Mimics, 3D Slicer, and Inobitec Medical Imaging Software, generating an interactive, high-quality 3D model from raw CT data by an experienced engineer or radiologist typically takes 2 to 8 hours, depending on the complexity of the anatomy (e.g., presence of large vessels, hernia size, quality of contrast enhancement). These time requirements represent a significant obstacle for routine use in high-demand clinical settings. Economic considerations. Implementation requires investment in specialized software (for example, commercial licenses for Materialise Mimics and Inobitec Medical Imaging Software can cost several thousand dollars per year) and dedicated time of a qualified specialist. These costs—estimated at several hundred dollars per model when accounting for personnel and software—are often not reimbursed by healthcare insurance systems, complicating large-scale economic justification. Need for professional training. Surgeons must learn not only to visualize 3D models but also to interpret them correctly and integrate the information into preoperative planning. Insufficient high-level evidence. Currently, the number of large prospective randomized studies convincingly demonstrating the superiority of 3D preoperative planning in terms of long-term functional outcomes (quality of life, recurrence rates) remains limited. Most available data are observational, emphasizing the need for further research. Future developments. Efforts to overcome these barriers include automation of segmentation using artificial intelligence, which promises to reduce processing time from hours to minutes, as well as the development of standardized, reimbursable clinical workflows.

Conclusion.

In summary, three-dimensional (3D) modeling represents not merely a technological innovation, but a fundamental shift in the approach to surgical management of hiatal hernias. It moves the focus from standardized procedural schemes toward personalized medicine, where the surgical strategy is determined by the unique anatomy of each patient. Current advantages of the technology include the objectification of preoperative diagnostics, optimization of decisions regarding the use of mesh implants, and navigational support during revision surgeries.

Future developments are associated with the integration of automated modeling into routine diagnostic workflows and the combination of virtual planning with the operative field through augmented reality technologies. The role of 3D modeling is particularly significant in complex and recurrent hiatal hernias, as it allows reduction of intraoperative complications, increases the likelihood of long-term surgical success, and ensures effective relief of reflux and dysphagia symptoms. Thus, 3D modeling opens new horizons in the surgical treatment of hiatal hernias, combining diagnostic precision with personalized therapeutic strategies.

Conflict of Interest.

None declared.

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რეზიუმე

3D მოდელირების შესაძლებლობები დიაფრაგმის საყლაპავის ხვრელის თიაქრების ქირურგიულ მკურნალობაში. ლიტერატურის მიმოხილვა.

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კვლევის მიზანი. ლიტერატურული წყაროების კომპლექსური ანალიზის საფუძველზე დახასიათდეს 3D მოდელირების ტექნოლოგიების გამოყენების თანამედროვე მდგომარეობა, პრაქტიკული შესაძლებლობები და პერსპექტიული მიმართულებები დიაფრაგმის საყლაპავის ხვრელის თიაქრების ქირურგიული მკურნალობის შემდეგ ასპექტებში: პათოლოგიის დიაგნოსტიკა; ჩარევის მოცულობისა და ტაქტიკის პრეოპერაციული დაგეგმვა; ინტრაოპერაციული ნავიგაცია; ქირურგიული მკურნალობის ეფექტიანობის შეფასება.

მასალა და მეთოდები. სისტემატური მიმოხილვა ჩატარდა PRISMA-ს სახელმძღვანელო პრინციპების შესაბამისად. 2010 წლიდან 2025 წლამდე პუბლიკაციების ძიება ჩატარდა. ძიებისა და ანალიზისთვის გამოყენებული იქნა სხვადასხვა მონაცემთა ბაზა, როგორიცაა PubMed, Web of Science, Scopus, eLIBRARY და CyberLeninka. კვლევის მეთოდები მოიცავდა ანალიტიკურ ანალიზს და მონაცემთა სინთეზს. მიმოხილვის ჩართვის კრიტერიუმები იყო ორიგინალური კლინიკური კვლევები, მიმოხილვითი სტატიები, კლინიკური შემთხვევები და პუბლიკაციები, რომლებიც ეძღვნებოდა 3D მოდელირების, კომპიუტერული ტომოგრაფიის ანატომიის, ვირტუალური და გაძლიერებული რეალობის ტექნოლოგიების გამოყენებას ჰიატალური თიაქრის და გასტროეზოფაგური რეფლუქსური დაავადების ქირურგიაში. ფილტრები გამოიყენებოდა ნიმუშის შესაზღუდად ინგლისურ და რუსულ ენებზე პუბლიკაციებით და ადამიანებზე ჩატარებული კვლევებით. განსაკუთრებული ყურადღება დაეთმო კვლევებს, რომლებიც შეიცავდა მონაცემებს ამ მეთოდების და გასტროეზოფაგიტის კლინიკური ეფექტურობისა და პრაქტიკული შედეგების შესახებ. ძიება ჩატარდა შემდეგი საკვანძო

სიტყვების გამოყენებით: „რეფლუქს-ეზოფაგიტი, ჰიატალური თიაქარი, კომპიუტერული ტომოგრაფია, პრეოპერაციული დაგეგმვა, ქირურგიული ნავიგაცია, 3D მოდელირება, გაძლიერებული რეალობა“.

კვლევის შედეგები. მიღებული შედეგების ანალიზი ადასტურებს, რომ 3D მოდელირების დანერგვა იწვევს მკურნალობის სტანდარტული პროტოკოლის მოდიფიკაციას. დიაგნოსტიკურ ეტაპზე ტექნოლოგია საშუალებას იძლევა სარწმუნოდ განისაზღვროს თიაქრული გამობერვის ტიპი და ზომა, შეფასდეს ოპერაციული ჩარევისთვის გადამწყვეტი მნიშვნელობის მქონე ანატომიური სტრუქტურები (საყლაპავის მუცლის სეგმენტის სიგრძე, დიაფრაგმის ფეხების განშლის სიდიდე, საყლაპავის შემოკლების ხარისხი — მისი არსებობის შემთხვევაში — და სისხლძარღვოვანი არქიტექტონიკის თავისებურებები). მიღებული მონაცემები საშუალებას აძლევს ქირურგს კომპლექსურად შეაფასოს პაციენტის ანატომიური თავისებურებები, განსაზღვროს ოპტიმალური ქირურგიული წვდომა (ლაპაროსკოპიული, რობოტული, თორაკალური, ღია) და აირჩიოს ყველაზე შესაფერისი ფუნდოპლიკაციის ტიპი (ჩერნოუსოვის, ნისსენის ან ტუპეს მეთოდი).

დასკვნა. 3D მოდელირების ტექნოლოგიების რუტინულ პრაქტიკაში ინტეგრაცია საშუალებას იძლევა კომპლექსურად ვიზუალიზდეს ანატომიური სტრუქტურები პათოლოგიური კერის გაზომვით და მისი სივრცითი მდებარეობის დადგენით მომიჯნავე ორგანოებსა და სისხლძარღვოვან სტრუქტურებთან მიმართებაში, კომპეტენტურად დაიგეგმოს ოპერაციული ჩარევის მოცულობა და ტაქტიკა, მინიმუმამდე დაიყვანოს ინტრაოპერაციული გართულებების რისკები და ამაღლდეს ჩატარებული ქირურგიული ჩარევების ეფექტიანობა.

საკვანძო სიტყვები: დიაფრაგმის საყლაპავის ხვრელის თიაქარი, 3D მოდელირება, კომპიუტერული ტომოგრაფია, პრეოპერაციული დაგეგმვა, რეფლუქს-ეზოფაგიტი.

ინტერესთა კონფლიქტი: არ არსებობს.