BMC Surgery

RESEARCH

Open Access

Predictive model for recurrence of incisional hernia constructed by CT abdominal wall imaging features

Qi He[1,2], Yunhua Wu[1], Gexin Xu[1,2], Zhixing Zhang[1], Dejan Gao[1,2], Lingzhi Nie[1] and Qingguo Du[1*]

Abstract

Background The recurrence rate after incisional hernia surgery is the most important concern for patients and surgeons, which not only causes pain to the patient but also adds additional medical costs. This study aims to investigate CT imaging features based on abdominal wall mechanics for recurrence after incisional hernia surgery.

Materials and methods We collected data from patients who were diagnosed with incisional hernia and underwent hernia repair from January 2017 to January 2022 in Shanxi Provincial People's Hospital. Based on Laplace's equation, an equation for spherical wall pressure, we further measured the preoperative abdominal wall thickness and abdominal wall radius of the patients by CT and measured the abdominal wall muscle area and visceral fat area at the third lumbar level by using Slice-O-Matic 5.0 software, and the sarcopenia index was further obtained by dividing the muscle area by the square of the height. Then, we analyzed their relationship with the postoperative recurrence of incisional hernia.

Results By univariate and multifactorial analyses, we found that excessive visceral adiposity, high BMI and sarcopenia were independent risk factors for incisional hernia recurrence. In further stratified analysis, we also found that patients with combined sarcopenia had a higher probability of recurrence. Our results found that visceral fat was a higher risk factor for incisional hernia recurrence than BMI.

Conclusion This study was a *retrospective study*. Based on the Laplace equation, sarcopenia and visceral fat are independent risk factors for recurrence after incisional hernia.

Keyword Incisional hernia, Recurrence, Visceral fat, Sarcopenia

Introduction

Incisional hernia is one of the most common abdominal wall hernias. Surgical repair is the most efficacious method for the treatment of incisional hernia, while the high recurrence rate after surgery seriously affects the outcome of its treatment and the recurrence rate can even reach 28% [1, 2]. It is important to identify these risk factor that affecting the recurrence of incisional hernia, which can help surgeon to reduce the recurrence rate and choice more rational surgical approach [3].

The recurrence of incisional hernia can be attributed to weakness of the abdominal wall and excessive intra-abdominal pressure [4]. The former usually caused by decreasing of muscle strength or lankness of fibrous tissue, such as advanced age, poor nutritional status and muscle damage. And the latter due to the abdominal obesity or this disease leading to increasing of abdominal pressure, such as chronic cough, constipation and urinary

*Correspondence:
Qingguo Du
dr_duqingguo@163.com
[1] The Second Department of General Surgery, Shaanxi Provincial People's Hospital, 256 West Youyi Road, Xi'an, Shaanxi 710061, China
[2] Department of General Surgery, Xizang Minzu University, 6 West Wenhui Road, Xianyang, Shaanxi 712082, China

difficulties. Presently, although many prediction models for incisional hernia recurrence have been established [5]; however, there are relatively few predictive models for incisional hernia recurrence based on abdominal wall mechanics.

Based on the risk factors that related to recurrence of incisional hernia, the forces exerted at various points of the abdominal wall under normal conditions are related to the volume of abdominal fat and the strength of the abdominal wall muscles, which is consistent with Laplace's equation [6], which is a equation related to the forces exerted on the wall of the representative sphere. Current studies have shown that CT provides a very comprehensive assessment of the abdominal cavity and abdominal wall, and CT-based indices of visceral fat and sarcopenia have been used in studies of the prognosis of many diseases [7]. Whereas visceral fat can represent intra-abdominal volume, and sarcopenia reaction the abdominal wall muscle strength. Therefore, we extracted the factors related to abdominal wall mechanics by CT and further established a new model for predicting recurrence after incisional hernia repair.

Material and methods

The methods section of this paper is based on the STROBE guidelines [8].

Patients

We enrolled patients who were diagnosed with incisional hernia and underwent hernia repair from January 2017 to January 2022 in Shanxi Provincial People's Hospital. All patients underwent abdominal CT examination before the operation. We excluded patients who were diagnosed with incarcerated hernia, patients with incision infection, tumor patients with peritoneal metastases, and patients with incomplete clinical data.

We collected data including age, sex, body weight, body mass index, recurrent incisional hernia, previous abdominal surgical history, surgical method, elective/emergency treatment, sarcopenia index, visceral fat area, abdominal wall thickness, hernia sac radius, mesh location, amount of blood loss, operative time, and anemia. All patients were followed up every 3 months until January 2023.

Changes in abdominal wall mechanics at the onset of incisional hernia

The mechanics of the abdominal wall refer to the changing law of the force and pressure on the abdominal wall under different circumstances. When the body is at rest, the pressure on the abdominal wall comes mainly from its own gravity and the weight of internal organs. This is consistent with Laplace's equation in the spherical coordinate system. After hernia repair, the mechanics of the abdominal wall also change. The destruction of the abdominal wall structure leads to an imbalance in the mechanics of the abdominal wall. At this point, the material and position of the patch after hernia repair is used for additional support and repair of the abdominal wall to restore normal function.

According to the mechanics of the abdominal wall, we can image the abdominal wall as a hemisphere. The pressure on the abdominal wall is related to the pressure in the intra-abdominal wall, the radius of the abdomen and the thickness of the abdominal wall. As intra-abdominal fat is a representative indicator of the contents of the abdominal cavity, we can measure visceral fat to reflect intra-abdominal pressure. The thickness of the abdominal wall is an indicator of the strength of the abdominal wall, so according to this formula, we measured the thickness of the abdominal wall around the peri-incisional hernia, as well as the distance from the abdominal wall to the spine at the site of the incisional hernia, which, in combination with the abdominal visceral fat, systematically responded to all the pressures on the abdominal wall at the site of the incisional hernia.

CT scan parameters

All CT scans were performed using a Philips 128-slice spiral CT, which included at least the third lumbar level. Other parameters were as follows: pitch 0.625, scanning time 0.35 s, matrix 51 2×51 2, and tube voltage 1 20 kV, 1 00 ~ 200 A. The reconstruction thickness was 5 mm. All patients were informed and signed informed consent before the scan. The abdominal CT images at the level of the 3rd lumbar vertebra were extracted and analyzed by using Slice-O-Matic 5.0 software [9]. The area of visceral fat, subcutaneous fat, and abdominal wall muscle at the third lumbar level was obtained based on the density (−29 to 150 Hu) and the muscle and visceral fat location, as shown in Fig. 1.

The sarcopenia index (SMI) is equal to the muscle area at the level of the third lumbar vertebra divided by the square of the height [10]. According to the previous literature [11], sarcopenia was defined as SMI < 53 cm^2/m^2 for males with BMI ≥ 25 kg/m^2, SMI < 43 cm^2/m^2 for males with BMI < 25 kg/m^2, and SMI < 41 cm^2/m^2 for females. The area of visceral fat area (VFA) was extracted by the CT scan, and $^{VFA \geq 100\ cm2}$ was defined as excess visceral fat [12]. We measured the thickness of the abdominal wall at four points 1 cm from the incisional hernia (above, below, left and right) and took the average value as the abdominal wall thickness. The radius of the abdominal cavity is the distance from the right and left abdominal walls proximal to the

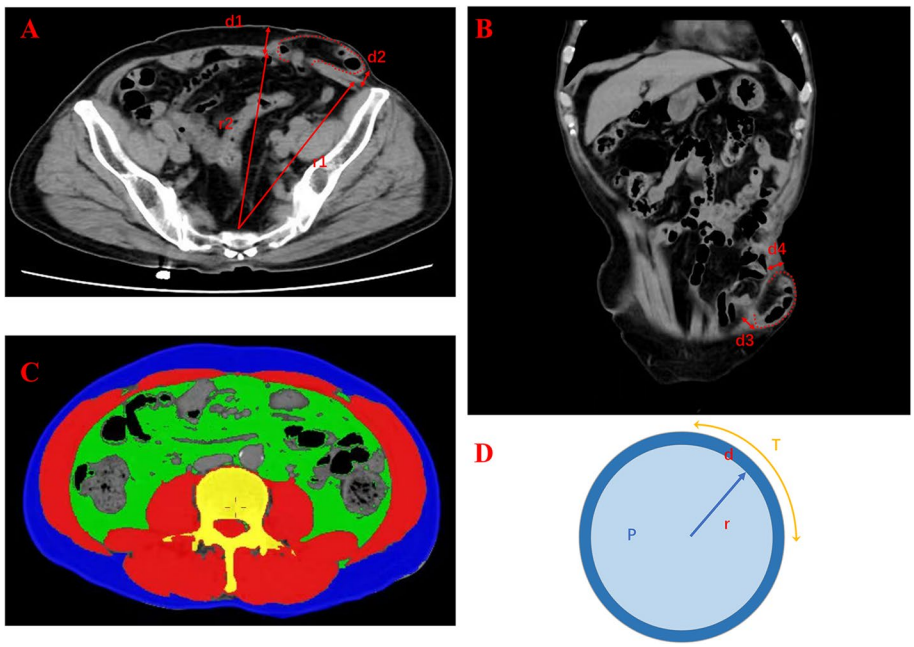

Fig. 1 Imaging feature extraction from CT. **A** The CT characteristics for incisional hernia patients at the median hernia site in the axis position. r1 and r2 are the distances of the left and right sides of the incisional hernia to the spine, and the average is the radius of the abdominal cavity. d1 and d2 represent the thickness of the abdominal wall at the left and right sides of the incisional hernia. The red circles mark the incisional hernia. **B** The CT characteristics for incisional hernia patients in the sagittal position. d1 and d2 represent the thickness of the abdominal wall at the upper and lower sides of the incisional hernia. The red circles mark the incisional hernia. **C** A typical image of the third lumbar level abdominal wall CT using Slice-O-Matic 5.0 software for image segmentation, where blue represents subcutaneous fat, red represents muscle area, green represents visceral fat, gray represents intestinal canal, and yellow represents bone. **D** The pressure equation for the surface of the sphere in the Laplace equation is T = P*r/2u. According to this equation, P is the pressure inside the sphere, r is the radius of the sphere and u is the thickness of the sphere

incisional hernia to the median spine in the CT plane at the median site of the incisional hernia.

Surgery and follow-up

All patients underwent bowel preparation prior to surgery, and the procedure was performed by a senior surgeon. The surgical approach was determined by the patient's specific situation and the surgeon's custom. For IPOM surgery [13], the surgeon uses a staple gun to secure the patch to the abdominal wall after suturing the hernia sac closed, ensuring a spiral staple for every 1 cm of patch. For the onlay and sublay [14] procedures, after removal of the hernia sac, we sutured the peritoneum, and then the patch was placed under or over the muscle and sutured to the abdominal wall fascia or muscle using absorbable sutures to ensure that the patch did not migrate. The patients were required to wear an abdominal band 7 days after surgery and avoid strenuous exercise for 3 months. We followed up with these patients every 3 months. The follow-up visit mainly included the presence of hernia recurrence and the occurrence of surgery-related complications.

Statistical analysis

The data were analyzed by using SPSS 26.0. All measured data that conformed to a normal distribution were measured using a t test [15], or if the data did not conform to a normal distribution, the data were measured with the Mann–Whitney U test. The χ-squared test or Fisher's exact test was used for qualitative data analysis [16]. The risk factors for incisional hernia recurrence were first analyzed by single-factor analysis, and those with meaningful data were further subjected to multifactor analysis. We also further explored the relationship between sarcopenia and incisional hernia recurrence [17, 18]. A statistical analysis of the effect of visceral fat and BMI on incisional hernia recurrence was also performed using a receiver operating characteristic curve (ROC). The ROC curve is mainly used to evaluate the quality of a binary classification model, and the classification effectiveness of the model can be measured by the AUC (area under the curve) in the ROC curve. $P < 0.05$ was considered statistically significant [19].

Result

Patients and data

In this study, we enrolled 160 patients who underwent incisional hernia repair in Shaanxi Provincial People's Hospital from January 2017 to January 2022. We excluded those who had combined incisional infection and combined postoperative intestinal fistula after surgery, and finally, we included 129 patients. Sixteen patients suffered hernia recurrence after surgery. Fifty patients underwent incisional hernia tension-free repair (Sublay + IPOM), 13 patients underwent hernia tension-free repair (Onlay), and 62 patients suffered IPOM. Four patients underwent hernia repair with simultaneous intestinal resection. No patients died during or after surgery. The age ranged from 45 to 75 years old, and there were 41 males and 88 females. Sixty-five patients had excess visceral fat, and 40 patients were diagnosed with sarcopenia.

Relationship between sarcopenia and recurrence of incisional hernia after surgery

To further demonstrate the relationship between sarcopenia and recurrence of incisional hernia, we analyzed the data between the patients with or without sarcopenia and found that there were no significant differences in the general data between the two groups, and the patients with sarcopenia had a higher recurrence rate after incisional hernia repair, as shown in Fig. 2.

Effect of visceral fat and BMI on recurrence of incisional hernia

We further explored two indicators that respond to obesity, namely, BMI and visceral fat, and by ROC curve analysis, we concluded that for incisional hernia recurrence, visceral fat has a larger area under the ROC curve (0.806 for BMI and 0.876 for visceral fat), as shown in Fig. 3. The analysis of risk factors for incisional hernia recurrence is shown in Tables 1 and 2.

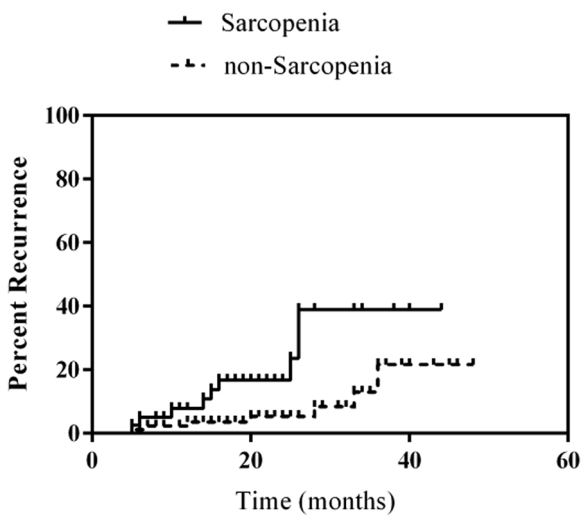

Fig. 2 Effect of combined sarcopenia on the recurrence of incisional hernia. $P = 0.0023$

Discussion

Recurrence after incisional hernia is an important complication affecting the postoperative period of incisional hernia [21]. Repeated surgeries not only increase the pain of patients but also add an additional financial burden to patients. It was very useful for us to identify hernia patients who were prone to recurrence before surgery [22], so we can intervene early to reduce the recurrence of hernia. In our study, according to the mechanics of the abdominal wall, we found that sarcopenia and excessive visceral fat are risk factors for the recurrence of incisional hernia. Our study provides new insight for the prediction of incisional hernia recurrence and may be useful for the selection of a surgical approach [9].

Sarcopenia is caused by loss of muscle mass; it not only represents the physical and nutritional status of the patient but is also an objective response to the strength of the abdominal wall, since the abdominal wall is mainly supported by the muscles and their fascia [23], and a decrease in muscle mass in patients with sarcopenia leads to a decrease in the strength of the abdominal wall, which subsequently predisposes patients to recurrence after hernia repair. Although there are various methods to detect sarcopenia, it is more common to use CT measurements of the muscle area at the third lumbar level in abdominal disease as the diagnostic criteria for sarcopenia used in this study. The present study summarizes and analyzes the clinical data and concludes that sarcopenia is an important risk factor for postoperative recurrence of incisional hernia.

According to the mechanics of the abdominal wall, the pressure on one point of the abdominal wall is inversely proportional to the thickness of the abdominal wall [24]. Sarcopenia, which represents the strength of the abdominal wall, was associated with recurrence of hernias, which is also consistent with mechanics of the abdominal wall. In addition to the reason why peri-incisional abdominal wall thickness is not associated with the recurrence of hernias, it may be related to the abnormal distribution of components in the abdominal wall; for example, fat is not the main factor affecting abdominal wall strength but can lead to an increase in the abdominal wall thickness we measured. Our study facilitates our selection of surgical approaches, such as choosing a strong patch for older patients with weak abdominal wall strength, and we should pay attention to the method of fixation of surgical sutures.

Table 1 Single-factor and multifactor analyses of risk factors for recurrence after incisional hernia

Project	Univariate analysis		Multivariate analysis	
	95% CI	p value	95% CI	p value
Gender(Male/Female)	0.073 (0.002-0.144)	0.129		
Age(every 1 years increase)	0.002 (0.001-0.004)	0.711		
BMI(every 1 kg/m^2 increase)	0.005 (0.003-0.007)	**0.017**	0.234 (0.056-0.969)	**0.045**
Sarcopenia(yes/no)	0.225 (0.090-0.360)	**0.020**	6.559 (1.823-23.592)	**0.004**
Excessive visceral fat(yes/no)	0.232 (0.118-0.346)	**0.001**	0.121 (0.028-0.527)	**0.005**
Abdominal wall thickness(every 1 cm increase)	0.065 (0.034-0.095)	0.088		
Abdominal diameter(every 1 cm increase)	0.001 (0.000-0.001)	0.053		
Hernial sac diameter(cm, every 1 cm increase)	0.024 (0.012-0.037)	0.539		
Type 2 diabetes(yes/no)	0.231 (0.057-0.404)	0.065		
Hypertension(yes/no)	0.219 (0.067-0.307)	0.062		
History of smoking(yes/no)	0.286 (0.015-0.556)	0.052		
Moderate to severe pulmonary dysfunction(yes/no)	0.101 (0.043-0.158)	0.064		
Surgical modalities(IPOM/Sublay /Onlay)	0.121 (0.040-0.202)	0.922		
With or without patches	0.111 (0.051-0.171)	0.316		
Patch material (bio-patch/chemical patch)	0.091 (0.042-0.140)	0.293		
Whether emergency surgery (yes/no)	0.100 (0.126-0.326)	0.812		
Blood loss(every 1 ml increase)	0.003 (0.001-0.005)	0.073		
Operation time(every 1 minute increase)	0.001 (0.001-0.002)	0.264		

Table 2 Analysis of general data of patients with or without combined sarcopenia [20]

Project	Sarcopenia	Non sarcopenia	t/X^2	P
Gender（Male/Female）	21/19	34/55	2.307	0.129
Age(years, $x^2 \pm s$)	62.1±13.98	63.07±12.22	-0.378	0.707
BMI(kg/m^2, $x^2 \pm s$)	23.29±2.9	24.06±2.11	-1.699	0.092
Excessive visceral fat (>100 cm^2,<100 cm^2)	13/27	52/37	2.810	0.094
Hernial sac diameter(cm, $x^2 \pm s$)	5.19±2.36	7.12±9.24	-1.834	0.069
Abdominal wall thickness(cm, $x^2 \pm s$)	2.7±0.84	2.83±0.86	-0.805	0.423
Abdominal diameter(cm, $x^2 \pm s$)	137.15±20.53	137.02±20.05	-0.029	0.977
Type 2 diabetes(yes/no)	5/35	14/75	2.111	0.146
Hypertension(yes/no)	9/31	23/66	0.165	0.684
Moderate to severe pulmonary dysfunction (yes/no)	33/7	76/13	0.176	0.675
History of smoking(yes/no)	10/30	4/85	11.994	0.001
Blood loss(ml, $x^2 \pm s$)	62.63±65.21	51.79±40.8	0.969	0.337
Operation time (min, $x^2 \pm s$)	157.15±71.75	152.1±76.6	0.361	0.719
Surgical modalities	0.55±0.5	0.49±0.5	45.46	0.562
Sublay+IPOM	16	34		
IPOM	18	44		
Onlay	4	9		
Hernia repair with intestinal anastomosis	2	2		
With or without patches(yes/no)	35/5	73/16	1.019	0.440
patch material（bio-patch/chemical patch）	24/14	64/19	5.024	0.129
Whether emergency surgery(yes/no)	2/38	8/81	0.614	0.433
anemia (yes/no)	8/32	3/86	2.495	0.114

Obesity is an important factor in the recurrence of imaging after incisional hernia surgery [25], and most of the current diagnoses of obesity are based on BMI. However, for patients with incisional hernia, visceral fat is more responsive to the intra-abdominal volume and pressure, which is also consistent with the index

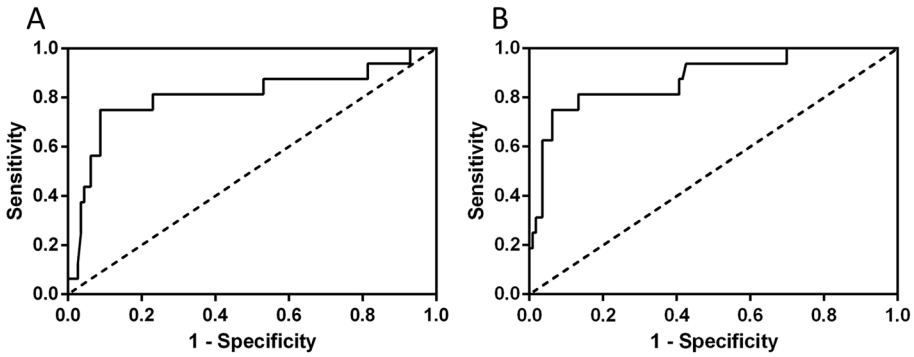

Fig. 3 ROC curve analysis of BMI and visceral fat in relation to incisional hernia recurrence. **A** The ROC curve for BMI in the analysis of incisional hernia recurrence, $P=0.017$; the area under the ROC curve was 0.806. **B** The ROC curve for visceral fat in the analysis of incisional hernia recurrence, $P=0.001$; the area under the ROC curve was 0.876

of intraspherical pressure based on the mechanics of the abdominal wall. Therefore, in this study, visceral fat was selected as the study subject, and its relationship with recurrence was investigated [26]. It was found that patients with high visceral fat were more likely to have recurrence of incisional hernia, suggesting that excessive visceral fat is a risk factor for recurrence of incisional hernia. In addition, the present study did not find a correlation between the abdominal radius and the recurrence of incisional hernia, probably because the method we measured did not fully reflect the distance from the point of force at the incisional hernia site to the spine.

In this study, we investigated the relationship between several abdominal wall and abdominal cavity features based on the mechanics of the abdominal wall for incisional hernia recurrence and concluded that sarcopenia and excess visceral fat distribution are independent risk factors for incisional hernia recurrence. However, this study also has many shortcomings: (1) it was retrospective, and there was some bias; (2) the sample size was small; (3) the definition of sarcopenia was based on literature standards and may not be consistent with this population; (4) the diagnosis of sarcopenia did not combine relevant clinical manifestations; and (5) the material of the patch is different from the structure of the abdominal wall, which may cause the pressure at this point after repair to be different from that of the normal abdominal wall, resulting in a certain bias, but the pressure at the patch site after repair is still in accordance with the mechanics of the abdominal wall, i.e., it is related to the abdominal contents and the strength of the abdominal wall. Moreover, this study found that the position of the patch was not associated with the recurrence of incisional hernia. In the next step of research, we need to further expand the sample size and develop diagnostic criteria for sarcopenia in people of different sexes and BMIs. In addition, it must be mentioned that when diagnosing sarcopenia, clinical criteria (muscle strength score, activity endurance score) are also very important, and future research needs to comprehensively evaluate clinical data.

In summary, based on noncontrast CT scanning for the diagnosis of sarcopenia combined with visceral fat area and abdominal wall thickness, this method is simple and reliable and has a certain predictive effect on patients with recurrence of incisional hernia. Although this view has not been affirmed by evidence-based medicine, we believe that it will play a greater role in the preoperative evaluation of incisional hernia, the selection of surgical methods and timing and individualized treatment.

Acknowledgements
This study was completed in the Shaanxi Provincial Key Laboratory of Infection and Immune Diseases, thanks again to all laboratory staff for their help in the experiment.

Authors' contributions
Qi He Collecting data and analyzing it, analyze data to make graphs and tables to assist Yunhua Wu in writing articles, and the main framework and quality control mentoring article. Gexin Xu was involved in the mapping of the article and patient follow-up and data collection, Zhixing Zhang And Dejian Gao assist with data collection, follow-up and review of patient information, Lingzhi Nie mainly responsible for patients' postoperative precautions and rehabilitation points, Qingguo Du guidance on writing essays and providing overall ideas for essays.

Funding
This study was supported by the Shaanxi Provincial People's Hospital Science and Technology Talent Support Plan under Grant 2021JY-15, the General Project of the Natural Science Foundation of Shaanxi Province - Youth Project under Grant No. 2022JQ-763 and the National Science Foundation of China Youth Program under Grant 82200563, the General Research Projects of Xi'an, Shaanxi Province Medical Research Projects under Grant No. 2023-YBSF-532.

Data availability
The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

This article has been approved by the Medical Ethics Committee of Shaanxi Provincial People's Hospital. All patients sign an ethical informed consent form.

Consent for publication

Not applicable.
Agree that this article was published in BMC surgery.

Competing interests

The authors declare no competing interests.

Received: 17 June 2024 Accepted: 12 March 2025
Published online: 24 May 2025

References

1. Ali F, Sandblom G, Wikner A, Wallin G. Laparoscopic ventral and incisional hernia repair using intraperitoneal onlay mesh with peritoneal bridging. Hernia. 2022;26(2):635–46.
2. Hauters P, Desmet J, Gherardi D, Dewaele S, Poilvache H, Malvaux P. Assessment of predictive factors for recurrence in laparoscopic ventral hernia repair using a bridging technique. Surg Endosc. 2017;31(9):3656–63.
3. Sneiders D, de Smet G, Hartog FD, et al. Outcomes of incisional hernia repair surgery after multiple rerecurrences: a propensity score matched analysis. World J Surg. 2021;45(5):1425–32.
4. Lyons M, Mohan H, Winter DC, Simms CK. Biomechanical abdominal wall model applied to hernia repair. Br J Surg. 2015;102(2):e133–9. https://doi.org/10.1002/bjs.9687. PMID: 25627126.
5. Mei T, Noguchi H, Otsu K, Shimada Y, Sato Y, Hisadome Y, Kaku K, Okabe Y, Nakamura M. Risk factors and optimal methods for incisional hernias after kidney transplantation: a single-center experience from Asia. Transplant Proc. 2021;53(3):1048–54. https://doi.org/10.1016/j.transproceed.2021.02.012. Epub 2021 Mar 13. PMID: 33726941.West JB. Fragility of pulmonary capillaries. J Appl Physiol (1985). 2013 Jul 1;115(1):1-15. https://doi.org/10.1152/japplphysiol.00229.2013 . Epub 2013 May 2. PMID: 23640584.
6. Vafaei S, Wen D. Modification of the Young-Laplace equation and prediction of bubble interface in the presence of nanoparticles. Adv Colloid Interface Sci. 2015;225:1–15. https://doi.org/10.1016/j.cis.2015.07.006. Epub 2015 Aug 1. PMID: 26320606. Dhillon RJ, Hasni S. Pathogenesis and Management of Sarcopenia. Clin Geriatr Med. 2017 Feb;33(1):17-26.10.1016/j.cger.2016.08.002. PMID: 27886695; PMCID: PMC5127276.
7. Tolonen A, Pakarinen T, Sassi A, Kyttä J, Cancino W, Rinta-Kiikka I, Pertuz S, Arponen O. Methodology, clinical applications, and future directions of body composition analysis using computed tomography (CT) images: a review. Eur J Radiol. 2021D;145:109943. https://doi.org/10.1016/j.ejrad.2021.109943. Epub 2021 Aug 30 PMID: 34839215.
8. Cuschieri S. The STROBE guidelines. Saudi J Anaesth. 2019;13(Suppl 1):S31–4. https://doi.org/10.4103/sja.SJA_543_18. PMID:30930717;PMCID:PMC6398292 .
9. Amini B, Boyle SP, Boutin RD, Lenchik L. Approaches to assessment of muscle mass and myosteatosis on computed tomography: a systematic review. J Gerontol A Biol Sci Med Sci. 2019;74(10):1671–8. https://doi.org/10.1093/gerona/glz034. PMID:30726878;PMCID:PMC7357454.
10. Smith KB, Smith MS. Obesity statistics. Prim Care. 2016;43(1):121-35. ix. https://doi.org/10.1016/j.pop.2015.10.001. Epub 2016 Jan 12. PMID: 26896205.
11. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, Schneider SM, Sieber CC, Topinkova E, Vandewoude M, Visser M, Zamboni M. Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the extended group for EWGSOP2. Sarcopenia: revised European consensus on definition and diagnosis. Age Aging. 2019;48(1):16–31. https://doi.org/10.1093/aging/afy169. Erratum in: Age Aging. 2019 Jul 1;48(4):601. PMID: 30312372; PMCID: PMC6322506. Li J, Wang Y, Wu L. The Comparison of eTEP and IPOM in Ventral and Incisional Hernia Repair: A Systematic Review and Meta-analysis. Surg Laparosc Endosc Percutan Tech. 2022 Jan 17;32(2):252-258.https://doi.org/10.1097/SLE.0000000000001035 .PMID: 35034068.
12. Naz A, Abid K, Syed AA, Baig NN, Umer MF, Mehdi H. Comparative evaluation of sublay versus onlay mesh repair for ventral hernia. J Pak Med Assoc. 2018;68(5):705–8 PMID: 29885166.
13. Basukala S, Tamang A, Rawal SB, Malla S, Bhusal U, Dhakal S, Sharma S. Comparison of outcomes of laparoscopic hernioplasty with and without fascial repair (IPOM-Plus vs IPOM) for ventral hernia: a retrospective cohort study. Ann Med Surg (Lond). 2022;80:104297. https://doi.org/10.1016/j.amsu.2022.104297 .PMID: 36045856; PMCID: PMC9422290. Kim HY. Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. Restor Dent Endod. 2017 May;42(2):152-155. https://doi.org/10.5395/rde.2017.42.2.152. Epub 2017 Mar 30. PMID: 28503482; PMCID: PMC5426219.
14. Ibrahim R, Abounozha S, Kheder A, Alshahri T. Incidence of seroma in sublay versus onlay mesh repair of incisional hernia. Ann Med Surg (Lond). 2020;61:155–7. https://doi.org/10.1016/j.amsu.2020.12.029. PMID: 33425349; PMCID: PMC7782192. Cantay H, Aydin U, Ozaydin I, Anuk T, Tasci SK, Yildiz U, Ermutlu D, Aksoy O. DIFFERENT SURGICAL METHODS IN COLON ANASTOMOSIS: EXPERIMENTAL STUDY. Arq Bras Cir Dig. 2022 Jun 24;35:e1662. 10.1590/0102-672020210002e1662. PMID: 35766607; PMCID: PMC9254599.
15. Stensrud MJ, Hernán MA. Why test for proportional hazards? JAMA. 2020;323(14):1401–2. https://doi.org/10.1001/jama.2020.1267. PMID: 32167523.
16. Berrett TB, Samworth RJ. USP: an independence test that improves on Pearson's chi-squared and the G-test. Proc Math Phys Eng Sci. 2021;477(2256):20210549. https://doi.org/10.1098/rspa.2021.0549. Epub 2021 Dec 8. PMID: 35153605; PMCID: PMC8652272.
17. Deerenberg EB, Henriksen NA, Antoniou GA, Antoniou SA, Bramer WM, Fischer JP, Fortelny RH, Gök H, Harris HW, Hope W, Horne CM, Jensen TK, Köckerling F, Kretschmer A, López-Cano M, Malcher F, Shao JM, Slieker JC, de Smet GHJ, Stabilini C, Torkington J, Muysoms FE. Updated guideline for closure of abdominal wall incisions from the European and American Hernia Societies. Br J Surg. 2022;109(12):1239–50. https://doi.org/10.1093/bjs/znac302. Erratum.In:BrJSurg.2022Nov10; PMID: 3602655.
18. Parikh KR, Al-Hawary M, Millet JD, Burney R, Finks J, Maturen K. Incisional Hernia Repair: What the Radiologist Needs to Know. AJR Am J Roentgenol. 2017;209(6):1239–1246. https://doi.org/10.2214/AJR.17.18137. Epub 2017 Oct 12. PMID: 29023150. Deerenberg EB, Henriksen NA, Antoniou GA, Antoniou SA, Bramer WM, Fischer JP, Fortelny RH, Gök H, Harris HW, Hope W, Horne CM, Jensen TK, Köckerling F, Kretschmer A, López-Cano M, Malcher F, Shao JM, Slieker JC, de Smet GHJ, Stabilini C, Torkington J, Muysoms FE. Updated guideline for closure of abdominal wall incisions from the European and American Hernia Societies. Br J Surg. 2022;109(12):1239–1250. https://doi.org/10.1093/bjs/znac302. Erratum in: Br J Surg. 2022 Nov 10;:. PMID: 3602655.
19. Beyene KM, El Ghouch A. Time-dependent ROC curve estimation for interval-censored data. Biom J. 2022;64(6):1056–74. https://doi.org/10.1002/bimj.202000382. Epub 2022 May 6. PMID: 35523738. Jairam AP, Timmermans L, Eker HH, Pierik REGJM, van Klaveren D, Steyerberg EW, Timman R, van der Ham AC, Dawson I, Charbon JA, Schuhmacher C, Mihaljevic A, Izbicki JR, Fikatas P, Knebel P, Fortelny RH, Kleinrensink GJ, Lange JF, Jeekel HJ; PRIMA Trialist Group. Prevention of incisional hernia with prophylactic onlay and sublay mesh reinforcement versus primary suture only in midline laparotomies (PRIMA): 2-year follow-up of a multicenter, double-blind, randomized controlled trial. Lancet. 2017 Aug 5;390(10094):567-576. 10.1016/S0140-6736(17)31332-6. Epub 2017 Jun 20. Erratum in: Lancet. 2017 Aug 5;390(10094):554. PMID: 28641875.
20. Omer E, Chiodi C. Fat digestion and absorption: Normal physiology and pathophysiology of malabsorption, including diagnostic testing. Nutr Clin Pract. 2024;39 Suppl 1:S6–16. https://doi.org/10.1002/ncp.11130.
21. Collaborative HART. Incisional hernia following colorectal cancer surgery according to suture technique: Hughes Abdominal Repair Randomized Trial (HART). Br J Surg. 2022;109(10):943–50. https://doi.org/10.1093/bjs/znac198. Erratum.In:BrJSurg.2022Dec13;110(1):126 PMID: 35979802.
22. Montgomery A. How to avoid an incisional hernia after cholecystectomy: use conventional multiport laparoscopy. Surgery. 2021;169(6):1278. https://doi.org/10.1016/j.surg.2021.02.051. Epub 2021 Apr 20. PMID: 33888319.

23. Crocetti D, Carbotta G, Cantelli F, Iorio O, Gurrado A, Sibio S, Brauneis S, Cavallaro G. Dietary protein supplementation helps in muscle thickness regain after abdominal wall reconstruction for incisional hernia. Am Surg. 2020;86(3):232–6 PMID: 32223803.
24. Aquina CT, Rickles AS, Probst CP, Kelly KN, Deeb AP, Monson JR, Fleming FJ. Muscle and adiposity research consortium (MARC). Visceral obesity, not elevated BMI, is strongly associated with incisional hernia after colorectal surgery. Dis Colon Rectum. 2015;58(2):220–7. https://doi.org/10.1097/DCR.0000000000000261. PMID: 25585081.
25. Basta MN, Mirzabeigi MN, Shubinets V, Kelz RR, Williams NN, Fischer JP. Predicting incisional hernia after bariatric surgery: a risk stratification model based upon 2161 operations. Surg Obes Relat Dis. 2016;12(8):1466–73. https://doi.org/10.1016/j.soard.2016.03.022. Epub 2016 Mar 23. PMID: 27425834.
26. Kallinowski F, Ludwig Y, Löffler T, Vollmer M, Lösel PD, Voß S, Görich J, Heuveline V, Nessel R. Biomechanics applied to incisional hernia repair - considering the critical and the gained resistance toward impacts related to pressure. Clin Biomech (Bristol, Avon). 2021;82:105253. https://doi.org/10.1016/j.clinbiomech.2020.105253. Epub 2020 Dec 29 PMID: 33401197.

Publisher's Note