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Computational Analysis and Classification of Hernia Repairs

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Abstract: Problems related to ventral hernia repairs (VHR) are very common, and evaluating them using computational methods can assist in selecting the most appropriate treatment. This study is based upon data from 3339 patients from different European countries observed during the last 12 years (2012–2023), which were collected by specialists in hernia surgery. Most patients underwent standard surgical procedures, with a growing trend towards laparoscopic surgery. This paper focuses on statistically evaluating the treatment methods in relation to patient age, body mass index (BMI), and the type of repair. Appropriate mathematical methods are employed to extract and classify the selected features, with emphasis on computational and machine-learning techniques. The paper presents surgical hernia treatment statistics related to patient age, BMI, and repair methods. The main conclusions point to mean groin hernia repair (GHR) complications of 19% for patients in the database. The accuracy of separating GHR mesh surgery with and without postoperative complications reached 74.4% using a two-layer neural network classification. Robotic surgeries represent 22.9% of all the evaluated hernia repairs. The proposed methodology suggests both an interdisciplinary approach and the utilization of computational intelligence in hernia surgery, potentially applicable in a clinical setting.

Keywords: hernia surgical repair; computational intelligence; feature extraction; classification; machine learning

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1. Introduction

Ventral hernia repair is one of the most common procedures performed by general surgeons and has been studied by many interdisciplinary research groups. Both open and minimally invasive approaches (including newly introduced robotic-assisted methods) [1] are possible and widely utilized. The influence of age [2,3] on the frequency of postoperative complications [4], delayed repairs, and emergency department visits is a broad research area that deserves close attention. The effect of the type of anesthesia (i.e., local, spinal, or general) on operative time and frequency of postoperative operations has also been studied [5]. Furthermore, numerous papers are dedicated to the relationship between body mass index (BMI), gender, and hernia development [6]. These studies are important to select appropriate fixation and mesh biomaterials to close the defect and to reduce postoperative complications like chronic pain, adhesion, and infection [7–10].

Many of these topics are closely intertwined with the rapid technological advancements in sensor systems, digital cameras, ultrasound methods [11], wireless communication links, material engineering, and 3D printing methods. Computer tomography serves as an efficient visualization tool that can aid in planning ideal hernia repair, particularly for incisional and larger hernias [12–14]. This enables hernia surgeons to identify any morphological tissue abnormalities during the preoperative planning phase, enhancing their decision-making capabilities. Technological advancements, such as three-dimensional volumetric analysis, augmented reality, machine learning, and the application of computational intelligence [15,16], contribute to the enhancement of patient care.

Hernia surgery is currently witnessing a technological boom. Mathematical and engineering methods are extensively employed in studies focused on the mechanical properties of mesh [17–19] and fixation techniques. Computational modeling has been utilized to assess the safety and efficacy of hernia mesh and biomaterial-based implants [20]. Artificial intelligence (AI) enables the integration of medical imaging, robotic hernia surgery [21–25], computer-aided hernia repair, and surgeon training. Furthermore, deep learning-based methods have been employed for automated surgical phase recognition [26], which incorporates information about the complexity of intra-abdominal and abdominal wall anatomy. The use of mesh in groin hernia repairs has demonstrated a reduction in the risk of hernia recurrence, although it may be associated with a slightly higher risk of chronic pain. Globally, over 1 million meshes are implanted in patients annually. In ventral hernia repairs, there is a significant rate of failure and reoperation, yet the reasons for such poor outcomes are not fully understood. Designing surgical meshes with suitable properties for abdominal hernias constitutes a distinct research area [27]. The mechanical behavior of both the abdominal wall and mesh elasticity is investigated using appropriate numerical models to propose appropriate tensile strength for specific hernia repairs. The use of AI integrated with a reliable database [22] can aid in identifying risk factors and determining whether mesh usage is recommended. However, the final decision should be made on an individual basis, considering the risks and benefits for each patient.

Classification of hernias (like all scoring systems used in medicine) based on their localization and size enables a comparison of research results of similar types of hernias and makes the planning of future studies easier. There are different nationwide datasets [28]. The European Hernia Society (EHS) classification of ventral hernias is a commonly adopted scoring system and is also used in the EHS registry [29,30]. Figure 1 shows this simple classification method and its graphical presentation.

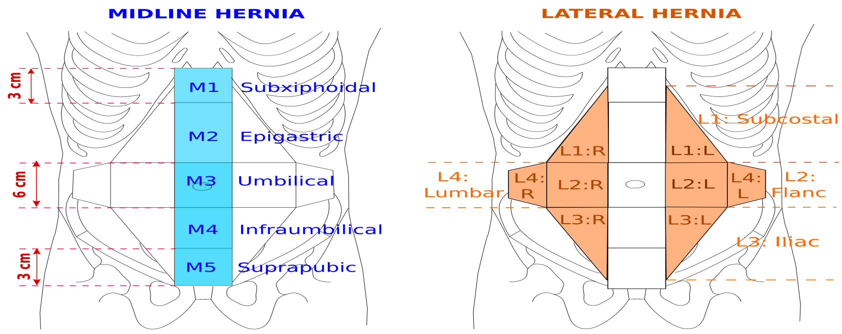

Figure 1. The EHS classification of incisional ventral hernias based on location.

Statistical analysis of significant variables in various surgical treatments enables researchers to compare different procedures and their outcomes. The methodology for mathematical data processing involves the utilization of general computational intelligence and digital signal processing methods, which share a common foundation in diverse applications [31,32], promoting a unified approach to data analysis through similar mathematical techniques. Specific methods include machine learning, feature extraction, and classification. Machine learning holds the potential to enhance the precision and safety of hernia surgery, reduce the risk of complications, and improve patient outcomes. However, further research is necessary to validate the effectiveness of machine learning in this context and ensure its successful integration into clinical practice.

The general methodology of digital signal processing finds wide applications in engineering, biomedicine, neurology, and the detection of motion disorders, among others.

Surgery represents a crucial domain where this methodology is applied, particularly in the context of multidimensional visualization tools. Technological advancements, especially in minimally invasive and robotic-assisted surgery, rely on the utilization of vast amounts of information, including surgical videos and the prediction of instrument trajectories using computational methods and automatic data analysis. These procedures help to return hernia contents to their natural position in the abdomen, repair the muscle wall, and reinforce it with mesh.

The present paper forms a contribution to the literature gap on computational intelligence in hernia surgery [15] to show the benefits of artificial intelligence in this field. The primary focus of this paper is to statistically evaluate the treatment methods in relation to patient age, body mass index, and the type of repair. Advanced mathematical techniques are employed to extract and classify relevant features, with a particular emphasis on computational and machine-learning methods. The objectives of the paper include the use of the European Hernia Society database to find facts about patients, surgery descriptions, complications, and possible statistical evaluations of its records. Specific algorithms are included in the proposed graphical user interface and are available for specialists on the web page, allowing the evaluation of selected facts in the given period of time. Objectives of the paper include (i) computational analysis of the abdominal repairs performed during the last 12 years and recorded in the European hernia database, (ii) the statistical survey of complications after the surgery, and (iii) application of machine-learning tools for classification of individuals with complications after the surgery.

2. Methods

The records from 3339 hernia surgeries were collected over the past 12 years in the clinical settings of selected European hospitals by the European Hernia Society (EHS). Table 1 presents the age distribution of hernia repairs conducted with and without the use of surgical mesh in the range of $\langle 2012, 2023 \rangle$ years. The collection of these records adhered to the ethical standards set by the institutional research committee following the 1964 Helsinki Declaration and its subsequent amendments. The anonymity of the obtained data was strictly maintained, and informed consent was obtained from all patients included in the database. The study received ethical approval from the Ethics Committee (UCT EK/7/2022). The datasets used and analyzed in the current study can be obtained from the corresponding author upon reasonable request. The processing and analysis of the data were conducted in MATLAB 2023b (MathWorks, Natick, MA , USA) computational environment.

Table 1. Basic demographics of the patient records (in the range of $\langle 2012, 2023 \rangle$ years) entered into the EHS registry with the number of females (F) and males (M) in the European database.

	Number of Patients		
Age	**Male**	**Female**	**Sum**
<25	39	7	46
$\langle 25, 35)$	152	56	208
$\langle 35, 45)$	283	123	406
$\langle 45, 55)$	544	141	685
$\langle 55, 65)$	641	142	783
$\langle 65, 75)$	577	198	775
>75	324	112	436
Sum	**256**	**779**	**3339**

Figure 2 presents the statistical survey of groin hernia repair (GHR) hernia surgery resulting from the European hernia database for the subset of records between the years of 2018 and 2023 with complete facts about the treatment. It presents the number of postoperative complications in seven age patients' categories and the percentage number of complications related to the complete number of complications in each age band. The type of postoperative complications is presented in Figure 2c. The relatively extensive number of complications motivates the study of their reasons to optimize the treatment process.

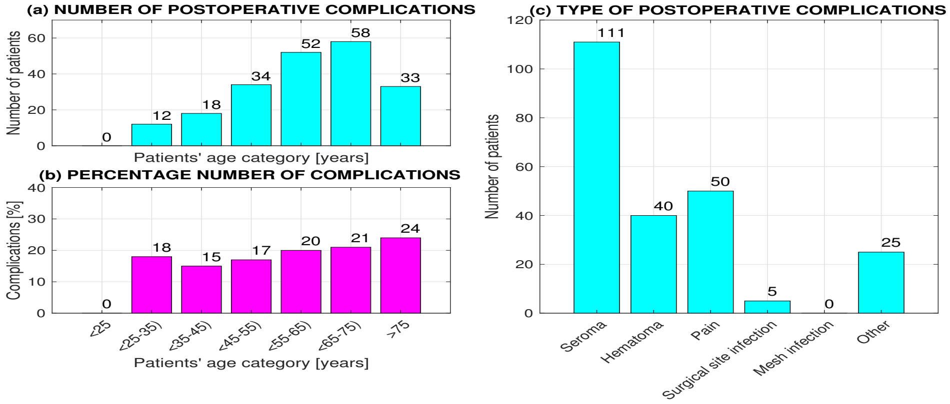

Figure 2. Statistical survey of GHR hernia surgery treatment resulting from the European hernia database for the set of 1088 patients recorded during last 6 years between years of 2018 and 2023 presenting (**a**) the number of postoperative complications in seven age patients' categories, (**b**) percentage number of complications related the complete number to complications in each age band, and (**c**) the type of postoperative complications.

Figure 3 illustrates the body mass index of selected individuals in the EHS registry with this information of GHR among hernia male and female patients with their mean values and their distribution. These summaries result from the use of the proposed graphical user interface.

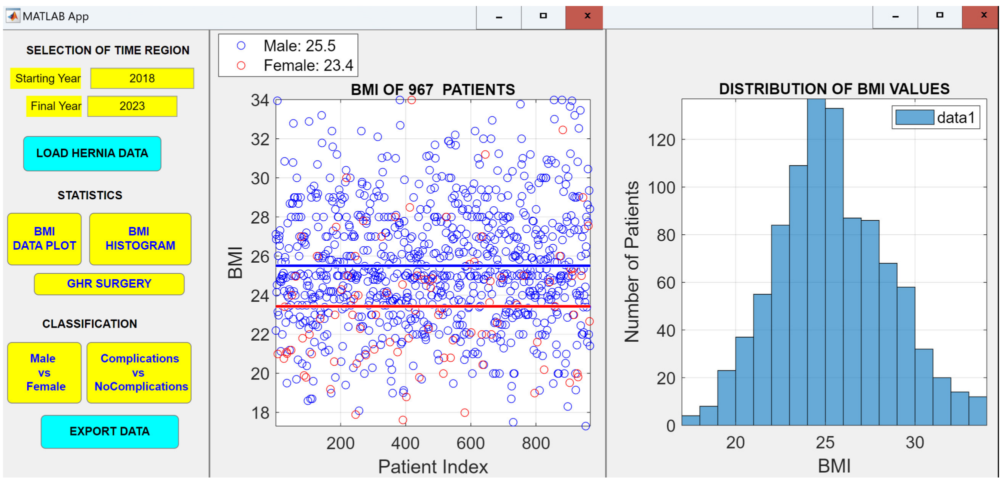

Figure 3. The body mass index of male and female GHR patients in the selected time period of 12 years (2012–2023) presented by the proposed graphical user interface based upon the hernia database.

Fundamental statistical methods for analysis of data sequence $\{x(n)\}_{n=1}^{N}$ include the evaluation of their variance

$$V = \frac{1}{N}\sum_{n=1}^{N}(x(n) - \bar{x})^2, \qquad \text{where } \bar{x} = \frac{1}{N}\sum_{n=1}^{N} x(n) \tag{1}$$

and their distribution by histograms followed by implementation of mathematical methods and general digital signal processing techniques [31]. The following feature extraction methods use both physiological and surgical data to classify the results of the hernia treatment in the present study.

The machine-learning methods involved the classification of selected features extracted from the hernia database. The set of Q column feature vectors $(\mathbf{p}_1, \mathbf{p}_2, \ldots, \mathbf{p}_j, \ldots \mathbf{p}_Q)$ was associated with a target class $(T_1, T_2, \ldots, T_j, \ldots, T_Q)$ defined by a surgery expert. Each feature vector $\mathbf{p}_j$ included R features, forming the feature matrix $\mathbf{P}_{R,Q}$. The present study uses the two-layer fully connected neural network with $S1$ = 10 and $S2$ = 2 units in the first and the second layers, respectively. The classification model includes the sigmoidal ($TF1$) and SoftMax ($TF2$) transfer functions in the first and the second layers described by the following relations:

$$\mathbf{A1}_{S1,Q} = TF1(\mathbf{W1}_{S1,R}\ \mathbf{P}_{R,Q}, \mathbf{b1}_{S1,1}) \tag{2}$$

$$\mathbf{A2}_{S2,Q} = TF2(\mathbf{W2}_{S2,S1}\ \mathbf{A1}_{S1,Q}, \mathbf{b2}_{S2,1}) \tag{3}$$

Network coefficients in matrices $\mathbf{W1}_{S1,R}$, $\mathbf{W2}_{S2,S1}$ and the associated vectors $\mathbf{b1}_{S1,1}$, $\mathbf{b2}_{S2,1}$ were optimized during the learning process. The final model allowed the processing of newly observed data and predicted their class membership.

The classification algorithm performed the detection of GHR surgery with complications (Class A: positive case) and without complications (Class B: negative case). The results are then distributed into four categories: true positive (*TP*), true negative (*TN*), false positive (*FP*), and false negative (*FN*). The accuracy (*AC*) of the algorithm is calculated as the ratio between correctly classified data points and all data points for a single set of surgeries by the following formula:

$$AC = \frac{TP + TN}{FP + FN + TP + TN} \tag{4}$$

The cross-validation error (*CV*) is expressed by relation:

$$CV = \frac{FP + FN}{FP + FN + TP + TN} \tag{5}$$

Sensitivity (true positive rate, *TPR*) and specificity (true negative rate, *TNR*) are defined by the following formulas:

$$TPR = \frac{TP}{TP + FN}, \quad TNR = \frac{TN}{TN + FP} \tag{6}$$

and they specify the ability to detect all positive or negative values, respectively.

Classification methods include the use of Bayesian models [33], SVM methods [34], and neural networks. In this paper, the *k*-fold cross-validation method is used during the optimization and validation process. Model selection strategies based on machine learning [35] gradually treat each fold as a test set while using the remaining folds as a training set. Each feature vector from the test set is classified using the data from the training set to evaluate the accuracy of the classification. The cross-validation error is then calculated as the fraction of incorrectly determined target classes and the number of all pattern values. In the present study, the 10-fold cross-validation method was applied.

3. Results

Analysis of hernia surgery is based on the database established by the European Hernia Society in 2011 and its use. The EHS registry collects demographic data, including BMI, age, gender, and comorbidities. Additionally, it records comprehensive information about the mesh utilized, type of repair, operative details, postoperative complications, patient satisfaction, and outcomes. Processing steps include:

1. Record of facts about each surgery performed by the member of the society that includes information about the patient, surgery description, and its results,
2. Statistical evaluation of all records in the database,
3. Password-protected access of EHS members to the web page allowing the evaluation of selected facts in the given period of time.

Table 2 provides the demographic composition of the total number of 3339 patients in the EHS database with 2048 Groin Hernia Repairs (GHR) and 1234 repairs of Primary Ventral Hernias (PVHR), Incisional Ventral Hernias (IVHR), and Parastomal Hernias (PHR).

Table 2. The demographic composition of the hernia database of GHR and PVHR/IVHR/PHR repairs during separate years.

Year	GHR			PVHR/IVHR/PHR			UNSPECIFIED	Total
	Male	Female	Sum	Male	Female	Sum		
2012–2017	35	2	37	28	41	69	0	106
2018	34	3	37	15	15	30	0	67
2019	54	12	66	22	33	55	1	122
2020	279	37	316	117	99	216	4	536
2021	396	41	437	190	166	356	8	801
2022	572	43	615	144	137	281	14	910
2023	495	45	540	135	92	227	30	797
Sum	1865	183	2048	651	583	1234	57	**3339**

Figure 4 presents the percentage ratio of operation types (open, laparoscopic, and robotic) during selected years of the GHR and PVHR/IVHR/PHR surgery. It is the evident increase in open and laparoscopic operations and decrease in robotic operations recorded in the EHS database.

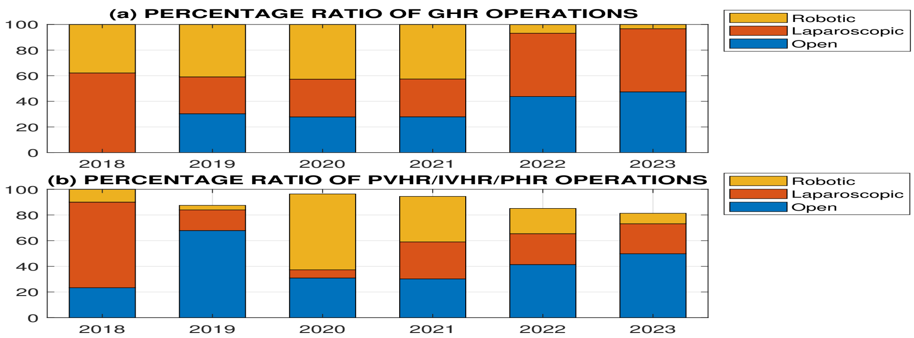

Figure 4. Percentage ratio of operation types (open, laparoscopic, and robotic) during selected years of (**a**) GHR surgery and (**b**) PVHR/IVHR/PHR treatment.

Table 3 presents the number of open repairs, minimally invasive procedures, and robotic-assisted repairs. Among the variables recorded in the EHS registry for minimally invasive surgical approaches, the following techniques are listed: totally extra-peritoneal access (TEP), extended view TEP (e-TEP), endoscopic trans-abdominal accesses (TAPP, TAPP ventral, and TARUP), endoscopic subcutaneous access (SCOLA), and endoscopic hybrid access, which combines endoscopic and open repair. The registry also includes data on robotic-assisted operations, specifically robotic extra-peritoneal (robotic e-TEP), robotic trans-abdominal (rTAPP ventral and rTARUP), as well as combined techniques involving robotic endoscopic trans-abdominal access (rTAPP), robotic endoscopic extra-peritoneal access (rTEP), and robotic hybrid access (combined robotic and open repair).

The graphical user interface (GUI) has been developed to extract specific information from the extensive and continuously expanding European hernia database. The required data can be processed using the proposed algorithm and presented to the user to analyze previous surgeries and propose the optimal solution for new patients. Figure 3 illustrates the body mass index of individuals in the EHS registry of GHR among hernia male and female patients with their mean values and their distribution. The total number of records acquired in the range of $\langle 2012, 2023 \rangle$ years was reduced to 1088 GHR patients with complete database records. This characteristic, which serves as a measure of body fatness, is calculated by dividing a person's weight (in kg) by the square of their height (in m). BMI is a significant factor associated with worse outcomes and plays a crucial role in decision-making regarding the type of operation, operative approach, and choice of mesh.

Table 3. Hernia repair technologies related to the hernia type including GHR (Groin Hernia) and PVHR/IVHR/PHR (Primary Ventral Hernia, Incisional Ventral Hernia, Parastomal Hernia) repairs during in the period between 2012 and 2023.

Year	Type of Repair	Repair Technology				
		Open	Endoscopic	Robotic	Other	Sum
2012–2017	GHR	0	37	0	0	37
	PVHR/IVHR/PHR	3	66	0	0	69
	Sum	**3**	**103**	**0**	**0**	**106**
2018	GHR	0	23	14	0	37
	PVHR/IVHR/PHR	7	20	3	0	30
	Sum	**7**	**43**	**17**	**0**	**67**
2019	GHR	20	19	27	0	66
	PVHR/IVHR/PHR	38	9	2	7	56
	Sum	**58**	**28**	**29**	**7**	**122**
2020	GHR	88	93	135	0	316
	PVHR/IVHR/PHR	68	14	130	8	220
	Sum	**156**	**107**	**265**	**8**	**536**
2021	GHR	122	129	186	0	437
	PVHR/IVHR/PHR	109	104	128	23	364
	Sum	**231**	**233**	**314**	**23**	**801**
2022	GHR	269	304	41	1	615
	PVHR/IVHR/PHR	122	71	58	44	295
	Sum	**391**	**375**	**99**	**45**	**910**
2023	GHR	256	266	18	0	540
	PVHR/IVHR/PHR	128	60	21	48	257
	Sum	**384**	**326**	**39**	**48**	**797**
SUM	GHR	755	871	421	1	2048
	PVHR/IVHR/PHR	475	344	342	127	1291
	TOTAL SUM	1230	1215	763	128	3339

The GUI and selected data from the EHS database are stored at the IEEE DataPort (http://ieee-dataport.org/11319, (accessed on 6 March 2024)). This repository also includes a video abstract of the paper. In Figure 5, the classification of GHR surgery outputs presenting the comparison of GHR surgery results with (207) and without post-surgery complications (881) based upon two features (BMI and age) for central areas of features are presented. Post-surgery complications occurred for approximately 19% of patients. Figure 5 displays the mean values of these two categories and c multiples of their standard deviations (c = 0.2, 0.3, and 0.5) without considering the gender of the patients.

A distribution of mesh GHR repairs for patients with various body mass indexes, ages, and gender is presented in Figure 6. Each BMI and age range is represented by its mean value within a 12-year range.

Figure 7 presents the evaluation of the absolute and relative postoperative complications of the treatment of GHR patients followed between the years of 2018 and 2023. The absolute and relative number of open, laparoscopic, and robotic operations during the last 6 years is presented in Figure 7c.

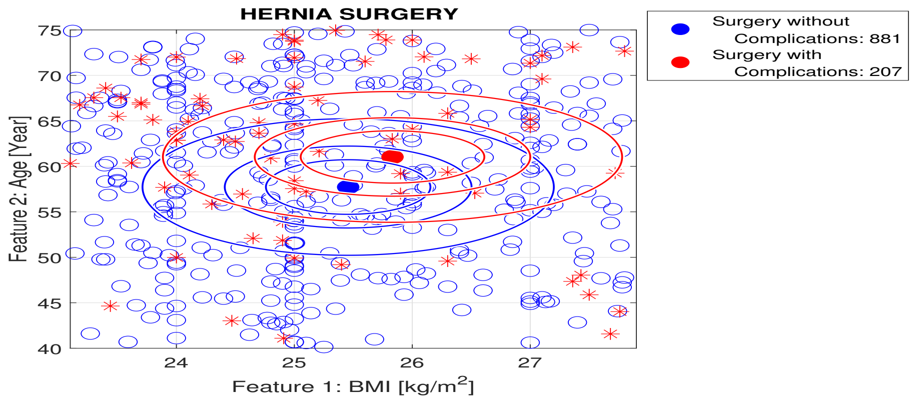

Figure 5. The relationship of age and BMI of patients to the GHR hernia surgery results and possible complications in the central areas of features with their mean values and *c* multiples of their standard deviations for *c* = 0.2, 3, and 0.5 (blue circles and red asterisks stand for surgeries without and with complications, respectively).

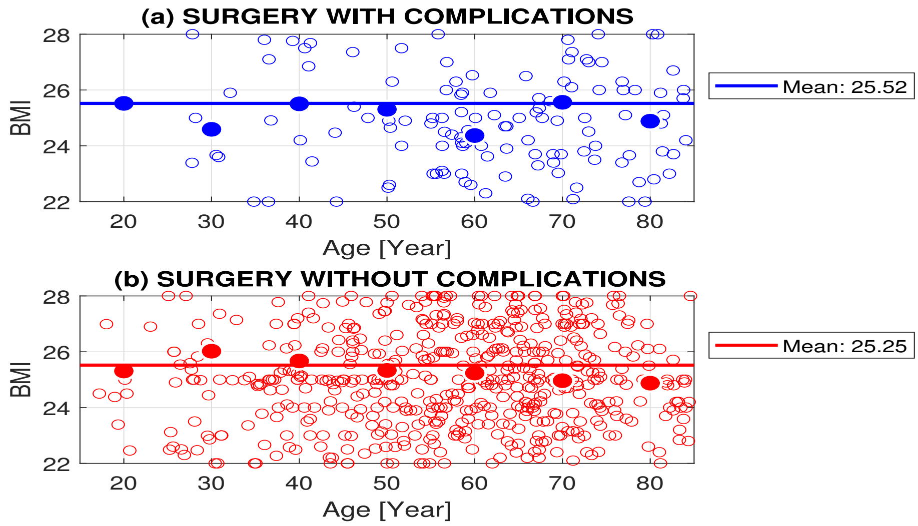

Figure 6. Distribution of GHR repairs for patients with various body mass indexes and age (**a**) for surgery with and (**b**) without complications (with blue and red solid dots standing for mean BMI values for patients in the age range of 10 years and surgeries without and with complications, respectively).

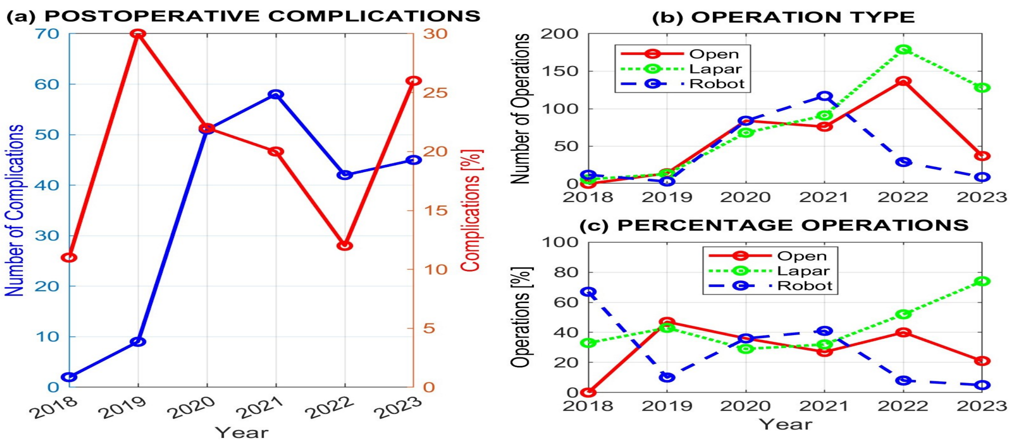

Figure 7. Resulting evaluation of GHR hernia treatment presenting (**a**) absolute and relative postoperative complications of 1088 patients followed between years of 2018 and 2023 and (**b**,**c**) absolute and relative number of open, laparoscopic and robotic operations during last 6 years.

Figure 8 presents the classification of GHR hernia surgery with mesh into two classes (A: Surgery with no complications, B: Surgery with complications) using the Bayesian, SVM, and the two-layer neural network methods, with BMI and age of the patient as distribution features. Results are very close, showing that patients with low BMI have a lower probability of surgery problems. The proposed algorithms, which include the classification of observed data and analysis of historical records, can contribute to the development of a decision-making tool to improve the outcomes of hernia operations and aid in preoperative planning. However, predicting the global impact of such a tool and its implications on health economics is challenging. Nonetheless, considering the significant number of hernia operations performed worldwide, its potential impact is likely to be substantial.

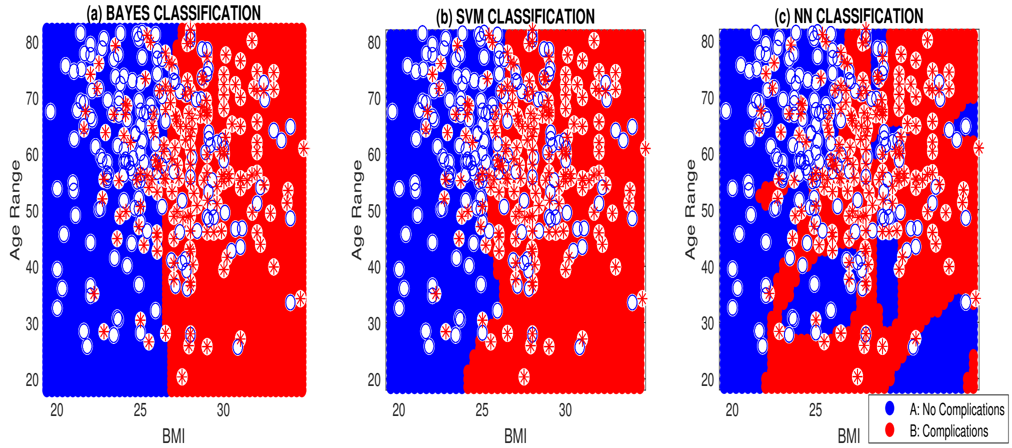

Figure 8. Classification of the GHR hernia surgery into two classes (A: Surgery with no complications, B: Surgery with Complications) by (**a**) the Bayesian, (**b**) the SVM, and (**c**) neural network methods using the BMI and age of the patient as distribution features.

The values of accuracy, specificity, sensitivity, and cross-validation errors of the GHR hernia surgery classification into two classes (A: Surgery with no complications, B: Surgery with complications) by the Bayes, SVM, and neural network methods are summarized in Table 4. The size of individual classes was equalized by the synthetic minority oversampling (SMOTE) technique to have datasets of similar sizes. The results include evaluation measures from the Bayesian, SVM, and the two-layer neural network models. The BMI and mean age of the patient were selected to form the pattern vector in all cases. Sensitivity (TPR), specificity (TNR), and cross-validation errors evaluated by the 10-fold method are also included in Table 4. The best results were obtained for the separation of GHR surgery without and with complications by the two-layer neural network classification with an accuracy of 74.4% and true positive rates of 77.7%.

Table 4. Accuracy (AC), specificity (TNR), sensitivity (TPR), and cross-validation errors (CV) for GHR hernia surgery classification into two classes (A: Surgery with no complications, B: Surgery with complications) evaluated by the Bayes, SVM, and neural network methods.

Classification Method	AC [%]	TNR [%]	TPR [%]	CV
Bayes method	68.2	70.6	65.9	0.31
SVM method	70.1	61.7	78.4	0.30
NN method	74.4	72.4	77.7	0.25

Figure 9 presents selected results based on the web access to the European hernia database and evaluation of specific questions. In the given case, it provides statistics on the type of surgery, intra-operative complications during the hernia surgery, and postoperative complications for the set of GHR patients treated during the period of 6 years between the years of 2018 and 2023.

Figure 9. Statistics of the type of surgery, intra-operative complications during the hernia surgery, and postoperative complications for the set of GHR patients included in the European hernia database and treated during the period of 6 years between the years of 2018 and 2023.

4. Discussion

Records of 3339 hernia surgeries with complete records performed during the last 12 years include 2048 GHR treatments and they indicate a higher proportion of male patients (75.4%) compared to female patients (22.9%) with mesh-based hernia repairs. While robotic surgery (performed in 22.9% of cases) can be beneficial, an open surgical approach or a combination of open and robotic approaches may be necessary for achieving optimal outcomes in cases of large or complex hernias [25]. Notably, the accuracy of distinguishing GHR mesh surgery with and without postoperative complications reached 74.4% with a true positive rate of 77.7% using a two-layer neural network classification. The problem of class imbalance was solved by the SMOTE technique. Post-surgery complications occurred in 19% of cases. Figure 5 illustrates the classification of GHR surgery outputs, presenting the comparison of GHR surgery results without and with post-surgery complications based upon two features (BMI and age). Complications after GHR are higher for patients with higher BMI and age.

This study is based on present records in the database of the European Hernia Society (https://www.europeanherniasociety.eu/ https://ehs-hernia-registry.com/, (accessed on 14 February 2024)), which serves as an alternative to other databases, including Foreningen Dansk Herniedatabase [36]. Registries have proven to be valuable tools in achieving better surgical results, a lower risk of complications, and a shorter recovery time. The advantages and limitations of different hernia databases are discussed in various references [37]. Our findings are consistent with other published evidence that focuses on comparing different patient groups and operative alternatives, particularly robotic-assisted minimally invasive and open techniques [38]. However, all these studies lack patient involvement [39]. The paper presents efficient access to database records through the proposed web page, which should be modified further in the future.

The use of computational methods shows how artificial intelligence is gradually transforming the approach to hernia surgery. In this field, machine learning has the potential to enhance accuracy and efficiency in several general ways:

- Preoperative planning: Machine-learning algorithms can analyze medical images such as CT scans and MRI to create 3D models of the patient's hernia and surrounding tissue. This enables surgeons to plan the surgery more precisely and reduce the risk of complications.

- Intra-operative assistance: During surgery, machine-learning algorithms can analyze real-time video footage from the surgical site and provide the surgeon with feedback on the location of the hernia, the depth of the incision, and the placement of surgical instruments.
- Postoperative monitoring: Machine-learning algorithms can analyze patient data, such as vital signs, laboratory results, and medication records, to predict the likelihood of postoperative complications and facilitate early intervention.

The present study is devoted to an analysis of GHR hernia surgeries of males/females and surgeries with/without complications for patients with different BMIs and ages. The accuracy of the classification system relies on the completeness and accuracy of the medical records used to identify the surgical procedures performed. The specificity of the classification system for groin hernia repairs is sufficiently high, as the type of surgical procedure performed is clearly defined, indicating the proportion of correctly identified individuals. The sensitivity of classification refers to its ability to correctly identify individuals with the condition being studied. Neural network models exhibit greater success in this context. Practical conclusions show that (i) open and laparoscopic surgeries are still often used, and (ii) machine-learning methods applied to classification point to the importance of preoperative treatment and rehabilitation.

Future efforts are needed to minimize tissue damage and postoperative complications. Understanding blood perfusion can help surgeons identify areas with good blood supply [40]. During hernia repair, especially in cases where mesh is used, ensuring adequate blood flow to the affected area can promote quicker healing and reduce the risk of complications.

To enable more detailed analysis and development of prediction models, more extensive data sets are necessary as well. Signal processing methods should include the study of mesh types, hospital stays, and postoperative complications. The rapid development of sensors and robotic technologies will motivate the more extensive study of robotic-assisted ventral hernia repairs and their influence on the number of postoperative complications. The use of synthetic mesh to reinforce the tissue wall during the repair of a large hernia is another topic for future studies. Mesh repair has a higher risk of complications such as infection, mesh migration, and bowel obstruction.

5. Conclusions

In conclusion, ventral hernias are a prevalent issue, and the application of computational methods for their evaluation can greatly assist in determining the most suitable treatment approach. By classifying hernia repairs into various classes, clinicians can better understand the type of surgery a patient has undergone, anticipate the potential complications and outcomes, and tailor postoperative management accordingly. This study utilized a comprehensive dataset consisting of patients from various European countries observed during the last 12-year period by hernia surgery specialists. The findings of this study provide valuable insights into the relationship between surgery hernia treatments, patient age, and repair technologies utilizing different types of meshes. The key conclusions highlight the classification of repair technologies based on patient BMI and age.

The clinical use of the hernia database is allowed to registered surgeons through a newly designed web page that implements the graphical user interface interconnecting the database, computational environment, and visualization tools. As there is a high percentage of problems after hernia surgeries, it is important to specify the most probable reasons for postoperative complications, study the best mesh material, and analyze surgery methods. Potential improvements and areas for further research include the collection of more data, analysis of computer tomography and magnetic resonance images, specification of more features, and application of different model architectures.

The proposed methodology signifies the importance of an interdisciplinary approach, emphasizing the collection of precise facts in the hernia database and the integration of computational intelligence in the evaluation of abdominal treatment. Furthermore, it suggests the potential application of these methods within a clinical environment. By leveraging computational techniques and machine-learning algorithms, healthcare professionals can make more informed decisions when selecting appropriate treatment options. This research represents a significant step forward in enhancing the efficiency and precision of hernia surgery, ultimately leading to improved quality of care. Moreover, it forms a contribution to the integration of computational intelligence and machine learning in surgeon training.

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Institutional Review Board Statement: The records from over 3300 hernia surgeries were collected over the past 12 years in the clinical settings of selected European hospitals. The collection of these records adhered to the ethical standards set by the institutional research committee following the 1964 Helsinki Declaration and its subsequent amendments. The anonymity of the obtained data was strictly maintained, and informed consent was obtained from all patients included in the database. The study received ethical approval from the Ethics Committee (UCT EK/7/2022).

Informed Consent Statement: Informed consent was obtained from all patients included in the database.

Data Availability Statement: The datasets used and analyzed in the current study can be obtained from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

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