Use of *NeuroXL* Classifier to predict postoperative complications in patients with primary and postoperative ventral hernia in morbid obesity

**The aim of the work:** based on the use of the program of multiparametric neural network clustering to analyze the results of examination and surgical treatment of patients with primary and postoperative ventral hernia in morbid obesity to identify a group of patients with high risk of complications in the postoperative period.

**Materials and Methods.** A comprehensive clinical-instrumental and laboratory examination of 237 patients with primary ventral and postoperative ventral hernia with concomitant morbid obesity with subsequent assessment of the nature of complications in the early and late postoperative periods was conducted. Patients were examined according to standards with this nosology, including general clinical, detailed study of all organs and systems of the body and local status (location, size, length of hernial protrusion) according to the EHS classification (2009). In the postoperative period, early (prolonged lymphorrhea, seroma, hematoma, infiltrate, marginal necrosis of the skin, suppuration) and late (mesh migration, meshomas, intestinal and ligature fistulas, mesh rejection, chronic pain, hernia recurrence) local and general (abdominal compartment syndrome, pulmonary embolism, pneumonia, myocardial infarction) complications. Clustering of subjects by groups using the add-on *NeuroXL* Classifier for Microsoft Excel was conducted for more in-depth analysis and in order to predict the complications in the postoperative period.

**Results and Discussion.** Analysis of cluster pictures during neural clustering based on clinical and anamnestic data and types of surgical interventions revealed that in predicting the risk of complications in the postoperative period based on combined changes, the combination of sex, obesity II-III and respiratory failure when own tissue hernioplasty and Onlay in patients were the most important. It should also be noted that the identified pattern primarily relates to the development of complications such as acute cerebrovascular accident, seroma and marginal necrosis of the postoperative wound. The lowest complication rate was observed in obese patients during laparoscopic hernioplasty and eMILOS (mini/less open sublay).

**Key words:** primary hernia; postoperative ventral hernia; obesity; neural network clustering; prognosis.

**Problem statement and analysis of recent research and publications.** Today, the issue of treatment of patients with primary ventral (PVH) and postoperative ventral hernia (POVH) remains one of the pressing problems of abdominal surgery [1, 2]. The increase of abdominal hernias incidence and the number of complications in the postoperative period are associated with an increase in the number of patients with morbid obesity, who are at particular risk for the incidence of complications after surgery [3, 4]. In Ukraine, 28.5% of the total population are obese, 48% are overweight. Most surgeons have different views on the treatment of these patients. No individualized approach to each patient, does not take into account its probable factors of hernia development, comorbidities, lack of sufficient experience and skills in choosing the optimal method of surgery lead to unsatisfactory treatment results [5]. Despite a significant number of surgical techniques of abdominal wall correction, the results of surgical treatment of ventral and postoperative ventral hernias are unsatisfactory, as evidenced by the large number of complications and high recurrence rate (4.5–42%). The morbid obesity in a patient can significantly change the course of the postoperative period and affect its prognosis [6].

The use of modern information programs greatly facilitates the solution of problems in predicting the complications in the postoperative period. Currently, neural networks are widely used to predict complications [7–12].

**The aim of the work:** based on the use of the program of multiparametric neural network clustering to analyze the results of examination and surgical treatment of patients with primary and postoperative ventral hernia in morbid obesity to identify a group of patients at high risk of complications in the postoperative period.

**Materials and Methods.** An in-depth comprehensive clinical-instrumental and laboratory examination of 237 patients with primary ventral and postoperative ventral hernia with concomitant morbid obesity was performed, followed by assessment of the nature of complications in the early and late postoperative periods. The study was conducted on the basis of the Department of Surgery of the Faculty of Postgraduate Education of I. Horbachevsky Ternopil National Medical University in the Surgical Department of Ternopil City Municipal Hospital No. 2 during 2019–2021. Obese patients with PVH and POVH...
were examined according to standards with this nosology, including general clinical, detailed study of all organs and systems of the body and local status (location, size, length of hernial protrusion) according to the EHS classification (2009). All patients underwent body mass index (BMI) determination and individual risk assessment of venous thromboembolic complications according to J. Caprini (2005).

There were 179 women (75.62 %) and 58 men (24.38 %). There were 36 (15.18 %) patients aged 20–44, 111 (46.78 %) – aged 45–60, 90 (38.04 %) – aged 61–75. The predominance of primary and postoperative ventral hernias of the middle location was 90.99 %. M1 defects were found in 6.81 %; M1-3 – 69.38 %; M3 – in 11.21 %, M4–5 – 3.59 %; L1, L2, L4 – 2.14 % of cases. Combined ML defects were in 6.87 % of patients. In the postoperative period, early (prolonged lymphorrhea, seroma, hematoma, infiltrate, marginal necrosis of the skin, suppuration) and late (mesh migration, meshomas, intestinal and ligature fistulas, mesh rejection, chronic pain, hernia recurrence) complications were assessed. BMI was used to assess overweight. According to BMI, overweight is established when it is bigger than 25.

| Table 1. BMI in obese patients (n=237). |
|----------------------------------------|
| BMI        | Number of patients, % (n=237) |
| 25–30      | 76 (32.07)                   |
| 30–35      | 107 (45.15)                  |
| 35–40      | 54 (22.78)                   |
| 40 and more| –                            |

The distribution of obese patients by age is shown in Table 2. Most patients with obesity of different classes were observed at the age of 45–60 – 111 (46.78 %).

According to our study patients aged over 45 were observed to have the main increase in body weight. Moreover, men begin to gain weight after about 40, and women – on average after 45–50. Henceforth, there is a tendency to increase body weight with age (average age in the group with obesity class I – (48.34±0.97), class II – (65.70±0.85), class III – (53.48±0.73)), but without significant age differences.

Obese patients are at the highest risk of anesthesia and surgery, as about 65–80 % of them are not examined at the time of hospitalization. At the same time, as the patient prepares for planned surgery, up to 3–4 comorbidities are detected.

**Results and Discussion.** Laboratory indicators and anamnesis

In order to establish the value of combined changes in the studied indicators for effective prediction of complications, neural network clustering of the results of a comprehensive clinical history and laboratory studies was performed based on the following indicators: age, sex, blood type, comorbidity: Age – age (1), S – sex (2), Ob – obesity I, II, III (3), CPI – chronic obstructive pulmonary disease (4), HeF – heart failure (5), Diab – diabetes mellitus (6), NDS – undifferentiated connective tissue dysplasia (7), VD – varicose vein disease (8), protein (10), bilirubin (11), creatinine (12), urea (13), AST (14), ALT (15), types of surgeries performed and complications of postoperative period (a total of 34 indicators). The indicator C was also determined for each patient as “1” in the absence of complications and “2” – their presence in the postoperative period.

Three clusters were selected for the neural network clustering algorithm. Figure 1 shows the results of the program clustering indicators. Cluster 1 includes 45.09 % of patients, cluster 2 – 29.91 %, and cluster 3 – 25.00 %.
As shown in Figure 2, the value of the complication rate in the postoperative period (34) was higher in cluster 3. Using a cluster picture, we can determine that this cluster had the highest rates of respiratory failure (4), protein levels (9), total bilirubin (10), urea (13) and AST (14). Among the postoperative complications, myocardial infarction (25), acute cerebrovascular accident (26) and suppuration of the postoperative wound (27) were more common in cluster 3.

In order to establish the value of the combined changes of certain parameters to predict the occurrence of complications, a neural network clustering of the results of clinical and anamnestic examination and types of surgical interventions was performed on the basis of a number of indicators. In order to establish the value of combined changes of parameters for the prognosis of ventral hernia complications, neural network clustering of patients’ results was performed based on gender indicators, types of surgical interventions (2–10), early (11–16) and late (23–25), complications on the wound, as well as general (17–22) complications: s – sex (1), PH – primary ventral hernias (2), AHP – own tissue hernia repair (3), On – onlay (4), In – inlay 5), Sub – sublay (6), CST – separation hernia repair (7), DLE – dermatolipectomy (8), laparoscopic hernia repair (9), eMILOS (mini/less open sublay) (10), Lym – lymphorrhea (11), Ser – seroma (12), Hem – hematoma (13), Sub – suppuration (14), LF – ligature fistulas (15), En – marginal necrosis (16), TELA – pulmonary embolism (17), ACS – abdominal compartment syndrome (18), Pneum – pneumonia (19), Inf – myocardial infarction (20), Stroke – stroke (21), MM – mesh migration (22), MC – mesh cysts (23). The indicator C was also determined for each patient as “1” in the absence of complications and “2” – their presence in the postoperative period.

### Table 3. Distribution of patients with obesity by type of surgery by age

| Type of surgery                        | Obesity class I (n=76) | Obesity class II (n=107) | Obesity class III (n=54) | Total (n=237) |
|----------------------------------------|------------------------|-------------------------|--------------------------|---------------|
|                                        | abs. | %    | abs. | %    | abs. | %    | abs. | %    | abs. | %    | abs. | %    | abs. | %    |
| Own tissue hernia repair               | 21   | 27.63| 17   | 15.88| 7    | 12.96| 45   | 18.98|      |       |      |       |      |       |
| Onlay                                  | 3    | 3.94 | 9    | 8.42 | 2    | 3.70 | 14   | 5.91 |      |       |      |       |      |       |
| Inlay                                  | 1    | 1.33 | 4    | 3.74 | -    | -    | 5    | 2.11 |      |       |      |       |      |       |
| Sublay                                 | 27   | 35.53| 31   | 28.97| 26   | 48.15| 84   | 35.44|      |       |      |       |      |       |
| CST + mesh                             | 2    | 2.63 | 2    | 1.87 | 1    | 1.85 | 5    | 2.11 |      |       |      |       |      |       |
| Laparoscopic hernia repair             | 6    | 7.89 | 19   | 17.76| 14   | 25.00| 39   | 16.46|      |       |      |       |      |       |
| eMILOS (mini/lessopensublay)           | 16   | 21.05| 25   | 23.36| 4    | 7.5  | 45   | 18.99|      |       |      |       |      |       |

**Fig. 1.** Percentage of patients enrolled in a particular cluster.

**Fig. 2.** Cluster picture – the values of parameters, including clinical history and laboratory parameters and the rate of complications in the postoperative period.
The parameters proposed by the program and three clusters were selected for the neural network clustering algorithm. Figure 3 shows the results of the program clustering indicators. Cluster 1 includes 25.00% of patients, cluster 2 – 29.91%, and cluster 3 – 45.09%.

As can be seen in Figure 4, the value of the complication rate in the postoperative period (23) was higher in cluster 1. With the help of a cluster picture, it can be determined that cluster 1 also had the highest rates of gender (1), obesity II–III (3) and respiratory failure (4). In this group, among the postoperative complications, acute cerebrovascular disorders (15), seroma (16) and marginal necrosis (17) of the postoperative wound were more common.

Conclusions. Analysis of cluster pictures in neural network clustering based on clinical history and laboratory indicators and the rate of complications in the postoperative period revealed that in predicting the risk of complications in the postoperative period based on the combined changes in the anamnesis, the most significant are the combination of sex, respiratory failure and elevated levels of protein, total bilirubin, urea and AST in the operated patients. The revealed regularity first of all concerns development of such complications as a myocardial infarction, acute disturbance of cerebral circulation and suppurations of a postoperative wound.

Analysis of cluster pictures during neural network clustering based on clinical and anamnestic data and types of surgical interventions revealed that in predicting the risk of complications in the postoperative period based on combined changes, the most important are the combination of sex, obesity II–III and respiratory failure when performing own tissue hernioplasty and Onlay in patients. It should also be noted that the identified pattern primarily relates to the development of complications such as acute cerebrovascular accident, seroma and marginal necrosis of the postoperative wound. The lowest complication rate was observed in obese patients during laparoscopic hernia repair and eMILOS (mini/less open sublay).

LIST OF LITERATURE
1. Helgstrand F. National results after ventral hernia repair / F. Helgstrand // Dan. Med. J. – 2016. – Vol. 63 (7). – P. B5258.
2. Piatnochka V. I. Outcomes of surgical treatment of obese patients with ventral and incisional hernias / V. I. Piatnochka // Arch. Balk. Med. Union. – 2019. – Vol. 54 (1). – P. 313–315. DOI: 10.31688/ABMU.2019.54.1.14.
3. Israelsson L. A. Prevention of incisional hernias: How to close a midline incision / L. A. Israelsson, D. Millbourn // Surg. Clin. North Am. – 2013. – Vol. 93 (5). – P. 1027–1040.
4. Risk factors for postoperative wound infections and prolonged hospitalization after ventral/incisional hernia repair / C. Kaoutzanis, S. Leichtle, N. Mouawad [et al.] // Hernia. – 2015. – Vol. 19 (1). – P. 113–123.
5. Improved outcomes in the management of high-risk incisional hernias utilizing biologic mesh and soft-tissue reconstruction: a single center experience / J. A. Skipworth, S. Vyas, L. Uppal [et al.] // World J. Surg. – 2015. – Vol. 38 (5). – P. 1026–1034.
6. Patel P. V. Ventral hernia repair in the morbidly obese patient: A review of medical and surgical approaches in the literature / P. V. Patel, A. M. Merchant // Bariatr. Surg. Pract. Patient Care. – 2014. – Vol. 9 (2). – P. 61–65.
7. Bishop C. M. Neural networks for pattern recognition / C. M. Bishop. – Oxford: Oxford University Press, 1995. – P. 504.
8. Martsenyuk V. On an indirect method of exponential estimation for a neural network model with discretely distributed delays.
П'ятночка В. І. Прогнозування розвитку рецидивів у хворих із первинними та післяопераційними вентральними гріжами із застосуванням багатопараметричної нейромережевої кластеризації / В. І. П'ятночка, І. Я. Дзюбановський, П. Р. Сельський // Медична інформатика та інженерія. – 2018. – № 4. – С. 41–45.

10. Марценюк В. П. Нейромережеве прогнозування складання студентами-медиками ліцензійного інтегрованого іспиту “Крок 1” на основі результатів поточної успішності та семестрового комплексного тестового іспиту / В. П. Марценюк, А. В. Семенець, О. О. Стаханська // Медична інформатика та інженерія. – 2010. – № 2. – С. 57–62.

REFERENCES

1. Helgstrand, F. (2016). National results after ventral hernia repair. Dan. Med. J., 63 (7), B5258.2.
2. Piatnochka, V.I. (2019). Outcomes of surgical treatment of obese patients with ventral and incisional hernias. Arch. Balt. Med. Union., 54 (1), 313-315. DOI 10.31688/ABMU.2019.54.1.14.
3. Isaelsen, L.A., & Millbourn, D. (2013). Prevention of incisional hernias: How to close a midline incision. Surg. Clin North Am., 93 (5), 1027-1040. DOI: 10.1016/j.suc.2013.06.0093.
4. Kaoutzanis, C., Leichtle, S., Mouawad, N., Welch, K.B., Lampman, R.M., Wahl, W.L., & Cleary, R.K. (2015). Risk factors for postoperative wound infections and prolonged hospitalization after ventral/incisional hernia repair. Hernia, 19 (1), 113-123. DOI: 10.1007/s10029-013-1155-y.
5. Skipworth, J.A., Vyas, S., Uppal, L., Floyd, D., & Shankar, A. (2014). Improved outcomes in the management of high-risk incisional hernias utilizing biologic mesh and soft-tissue reconstruction: a single center experience. World J. Surg., 38, 1026-1034. DOI: 10.1007/s00268-013-2442-6.
6. Patel, P.V., & Merchant, A.M. (2014). Ventral hernia repair in the morbidly obese patient: A review of medical and surgical approaches in the literature. Bariatr. Surg. Pract. Patient Care, 9 (2), 61-65. DOI: 10.1089/bari.2014.0008.
7. Bishop, C.M. (1995). Neural networks for pattern recognition. Oxford: Oxford University Press.
8. Martsenyuk, V. (2017). On an indirect method of exponential estimation for a neural network model with discretely distributed delays. Electron. J. Qual. Theory Differ. Equ., 23, 1-16. DOI: 10.14232/ejqtde.2017.1.23.
9. Piatnochka, V.I., Dziubanovskyi, I.Ya., & Selskyi, P.R. (2018). Prognostuvannia rozvytku retsydyviv u khvorykh iz pervynnymy ta pisliaoperatsiinymy ventralnymy hryzhamy hryzhamy iz zastosuvanniam bahato parametrychnoi neiromerezhevoi klasteryzatsii [Prediction of recurrence development in patients with primary and postoperative ventral hernias using multimetric neural network clustering]. Medychna informatyka ta inzheneriia – Medical Informatics and Engineering, 4, 41-45. DOI: https://doi.org/10.11603/mie.1996-1960.2018.4.9843 [in Ukrainian].
10. Martsenyuk, V. (2017). Indirect method of exponential convergence estimation for neural network with discrete and distributed delayed. Electron. J. Differ. Equ., 246, 1-12. Retrieved from: http://ejde.math.txstate.edu or http://ejde.math.unt.edu.
11. Shepherd, A.J. (1997). Second-order methods for neural networks: Fast and reliable training methods for multi-layer perceptrons. Shepherd. London: Springer.
12. Martsenyuk, V.P., Semenets, A.V., & Stakhanska, O.O. (2010). Neyromerezheve prohnozuvannia skladannia studentamy-medykamy litsenziinoho intehrovanoho ispytu “Krok 1” na osnovi rezultativ potochnoi uspishnosti ta semestrovoho kompleksnoho testovoho ispytu [Neuronetwork prediction of license integrated exam “Krok 1” passing based on current results and semester complex test exam for medical students]. Medychna informatyka ta inzheneriia – Medical Informatics and Engineering, 2, 57-62. DOI: https://doi.org/10.11603/mie.1996-1960.2010.2.112 [in Ukrainian].

Електронна адреса для листування: vladymyrpiatnochka@gmail.com.
В. І. П'ЯТНОЧКА, І. І. ДОВГА
Тернопільський національний медичний університет імені І. Я. Горбачевського МОЗ України

ВИКОРИСТАННЯ ПРОГРАМ “NEUROXLCLASSIFIER” З МЕТОЮ ПРОГНОЗУВАННЯ УСКЛАДНЕНЬ У ПІСЛЯОПЕРАЦІЙНОМУ ПЕРІОДІ В ПАЦІЄНТІВ НА ПЕРВИННУ ТА ПІСЛЯОПЕРАЦІЙНУ ВЕНТРАЛЬНУ ГРИЖУ ЗА УМОВ МОРБІДНОГО ОЖИРІННЯ

Мета роботи: на основі використання програми багатопараметричної нейромережевої кластеризації проаналізувати результати обстеження та хірургічного лікування пацієнтів на первинну та післяопераційну вентральну грижу за умов морбідного ожиріння для виділення групи пацієнтів із високим ступенем ризику виникнення ускладнень в післяопераційному періоді.

Матеріали і методи. Проведено комплексне клініко-інструментальне та лабораторне обстеження 237 пацієнтів на первинну вентральну та післяопераційну вентральну грижу із супутнім морбідним ожирінням з подальшим оцінюванням характеру ускладнень у ранньому та пізнім післяопераційному періодіх. Обстеження пацієнтів проводили відповідно до стандартів із даною нозологією, включно загальномедичних, детального дослідження стану всіх органів і систем організму та локального статусу (локалізації, розміру, прогностичності грижового випинання) відповідно до класифікації EHS (2009). У післяопераційному періоді оцінювали ранні (тривала лімфорея, серома, гематома, інфільтрат, крайовий некроз шкіри, нагноєння) та пізні (транспозиція сітки, мешоми, кишкові та лігатурні нориці, відторгнення сітки, хронічний біль, рецидиви грижі) місцеві і загальні (абдомінальний компартмент-синдром, тромбоемболія легеневої артерії, пневмонія, інфаркт міокарда) ускладнення. Для більш глибокого аналізу та з метою прогнозування виникнення ускладнень проведено кластеризацію досліджуваних по групах із використанням надбудови NeuroXL Classifier для програми Microsoft Excel.

Результати досліджень та їх обговорення. Аналіз кластерних портретів при проведенні нейромережевої кластеризації на основі клініко-анамнестичних даних та типів проведених операційних втручань виявив, що при прогнозуванні ризику ускладнень у післяопераційному періоді на основі поєднаних змін найбільш значення мають поєднання статі, ожиріння ІІ-ІІІ та дихальної недостатності при виконанні власнетканевої герніопластики та Onlay у пацієнтів. Треба також зазначити, що виявлена закономірність насамперед стосується розвитку таких ускладнень, як гостре порушення мозкового кровообігу, серома і крайовий некроз післяопераційної рані. Найнижчий показник ускладнень спостерігали в пацієнтів з ожирінням при виконанні лапароскопічної герніопластики та eMILOS (mini/less open sublay).

Ключові слова: первинна грижа; післяопераційна вентральна грижа; ожиріння; нейромережева кластеризація; прогнозування.