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   Książki:
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   Calpin C, Macarthur C, Stephens D, et al. Effectiveness of prophylactic inhaled steroids in childhood asthma: a systemic review of the literature. J Allergy Clin Immunol, 1997; 100: 452–457 . doi: 10.1016/s0091-6749(97)70134-9

   Books:
   Rudzki E. Alergia na leki: z uwzględnieniem odczynów anafilaktycznych i idiosynkrazji. Lublin, Wydawnictwo Czelej, 2002

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Dear Readers!

It is with pleasure that we place the fourth issue of the 102nd volume of Military Physician in your hands. Closing the year 2024, this issue summarises the work and research in the field of medicine, discussing the latest developments and practical solutions. As always, we strive to ensure that the papers presented offer support for all specialists.

I particularly recommend a paper on the properties of nebulisation aerosol cloud. This is a key topic for the treatment of patients with respiratory conditions, particularly in the context of therapy optimisation. In the issue, you will also find an important study on the strategic medical evacuation of the personnel of Polish military contingents. These issues are essential for ensuring the safety of our soldiers participating in foreign missions.

Also noteworthy are studies devoted to reconstruction of facial bite wounds, as well as research on pulmonary diagnosis in patients with lung cancer, which is an important contribution to the development of modern diagnostic approaches.

At the end of this busy year, I would like to wish you health, success and professional fulfilment for 2025. May the coming months bring you job satisfaction and new opportunities for scientific development.

*Prof. Bolesław Kalicki, MD, PhD*

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# TABLE OF CONTENTS

## CASE REPORTS

# A HISTORY OF THE PARATHYROID GLANDS: FROM EARLY MISUNDERSTANDINGS TO MODERN CONCEPTS

## Historia przytarczyc: od wczesnych nieporozumień do współczesnych koncepcji

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**Abstract**

The parathyroid glands are small organs responsible for regulating calcium-phosphorus metabolism in the body. They were discovered in 1852 by Richard Owen. A comprehensive description of the parathyroid structure in humans was presented by Sandström in 1880. Several years later, Gley observed a connection between parathyroid damage and tetany. In 1908, MacCallum and Voegtlin suggested the impact of parathyroids on calcium metabolism, attributing tetany to hypocalcaemia following their removal. The link between parathyroid pathology and skeletal changes was noted by Erdheim in 1906. Another pivotal event was the isolation of parathyroid extract, independently accomplished by Hanson in 1923 and Collip in 1925. Mandl made history as the first surgeon to successfully perform parathyroidectomy due to a parathyroid adenoma in 1925. In the mid 20th century, Albright conducted extensive studies on hyperparathyroidism, distinguishing between primary, secondary, and tertiary hyperparathyroidism. The purification of the parathyroid hormone and the development of laboratory tests to assess its blood levels facilitated the diagnosis of parathyroid disorders, contributing to a significant increase in surgeries in the late 1980s. The turn of the 19th and 20th centuries marked a period of significant development in parathyroid imaging techniques and minimally invasive surgery. This article delineates key events in the history of parathyroids that have shaped contemporary knowledge and contributed to the development of effective methods for the diagnosis and treatment of parathyroid diseases.

**Streszczenie**

Przytarczyce są niewielkimi gruczołami, które odpowiadają za regulację gospodarki wapniowo-fosforanowej w organizmie. Zostały odkryte w 1852 roku przez Richarda Owena, natomiast pełnego ich opisu u ludzi dokonał Sandström w 1880 roku. Kilkanaście lat później Gley zauważył związek między uszkodzeniem przytarczyc a występowaniem tężyczki. W 1908 roku MacCallum i Voegtlin zasugerowali wpływ przytarczyc na metabolizm wapnia, a tężyczkę przypisali hipokalcemii spowodowanej ich usunięciem. Związek między patologią przytarczyc a zmianami kostnymi został stwierdzony w 1906 roku, dzięki badaniom Erdheima. Kolejnym przełomowym wydarzeniem była izolacja ekstraktu przytarczyc, przeprowadzona niezależnie przez Hansona w 1923 roku i Collipa w 1925 roku. Mandl przeszedł do historii jako pierwszy chirurg, który przeprowadził skuteczną paratyroidektomię z powodu guza przytarczyc, co miało miejsce w 1925 roku. Najobszerniejsze badania na temat nadczynności przytarczyc przeprowadził w połowie XX wieku Albright, który zróżnicował pierwotną, wtórną i trzeciorzędową nadczynność przytarczyc. Oczyszczenie hormonu przytarczyc i opracowanie testów laboratoryjnych do pomiaru jego stężenia we krwi ułatwiło diagnostykę chorób przytarczyc, co przyczyniło się do znacznego wzrostu liczby operacji pod koniec lat 80. XIX wieku. Przełom XIX i XX wieku był okresem istotnego rozwoju technik obrazowania przytarczyc i chirurgii małoinwazyjnej. W niniejszym artykule opisano najważniejsze wydarzenia w historii przytarczyc, które ukształtowały współczesną wiedzę oraz przyczyniły się do opracowania skutecznych metod diagnostyki i leczenia chorób przytarczyc.

**Keywords:** history; parathyroid glands; tetany; parathyroid surgery; osteitis fibrosa cystica

**Słowa kluczowe:** historia; przytarczyce; tężyczka; chirurgia przytarczyc; włóknisto-torbielowate zwyrodnienie kości

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## Introduction

The parathyroid glands are small endocrine organs producing parathyroid hormone (PTH), which plays a key function in regulating calcium and phosphate metabolism in the body. First reports on parathyroid glands appeared in the mid 19th century, making these organs the most recently discovered anatomical structures in humans. Currently, we have extensive knowledge about the parathyroid glands and advanced diagnostic and therapeutic approaches to manage their dysfunctions. Although relatively short, the history of these small glands is full of misunderstandings, speculations and intriguing anecdotes. This paper highlights key events and discoveries that have significantly contributed to the understanding of the role of the parathyroid glands in the human body.

## Discovery of the parathyroid glands

The first description of the parathyroid glands dates back to the mid 19th century, when Richard Owen, a prominent British surgeon and anatomist, drew attention to independent anatomical structures located in the thyroid region during a necropsy of an Indian rhinoceros [1, 2]. In 1834, the Zoological Society of London purchased an Indian rhinoceros, which for 15 years was the main attraction at London Zoo. The animal died in November 1849 as a result of injuries inflicted by an elephant. During the winter months of late 1849 and early 1850, Richard Owen, who was a professor of Comparative Anatomy and a conservator of the Hunter's Museum at the Royal College of Surgeons in England at that time, conducted a detailed post-mortem examination of the 2-tonne animal, and then presented his findings to the Zoological Society of London on 12 February 1850 [1]. In the third part of his report, entitled 'Thoracic organs', Owen described the parathyroid gland for the first time as 'a small compact yellow glandular body attached to the thyroid at the point where the veins emerged' [1]. Although he did not perform a histological examination or speculate on the function of the newly identified structure, he fixed it along with the surrounding tissues, assuming that it might play an important role. The specimen was classified as RCSHM/L333.1 and is still available in the Hunter Museum in London. The entire post-mortem report on the rhinoceros was published in the fourth volume of Transactions of the Zoological Society of London. Unfortunately, the brief mention of a small anatomical structure was ignored among the extensive anatomical descriptions of the rhinoceros and Owen's discovery went unnoticed for the next 100 years. It was not until 1953 that British anatomist Alexander Cave, while analysing the Hunter Museum exhibits, discovered that Owen's paper, published on 2 March 1852, featured the first-ever description of the parathyroid glands, preceding all other reports on these organs [1].

Prior to this event, Ivar Viktor Sandström, a Swedish medical student who presented the first comprehensive description of the human parathyroid glands, was considered the discoverer of the these organs [1, 3]. In 1877, Sandström discovered 'a small organ, hardly as big as a hemp seed, which was enclosed in the same connective tissue capsule as the thyroid, but could be distinguished there from by a lighter colour' during a necropsy of a dog at the Department of Anatomy at Uppsala University. He then examined 50 human cadavers and found four glands in 43 of them, two on each side of the thyroid gland. Due to their location, he named the organs '*glandula parathyroideae*', i.e. parathyroid glands [4]. Hoping to make the discovery of the new organ more widely known, Sandström's findings were sent to a German journal, but the article was considered too long and rejected [3]. Finally, the paper was published in 1880 in a local Swedish journal [4]. In a 30-page paper, which contained many handwritten drawings and schematic images, Sandström thoroughly described the location, size, colour, variety of shapes and histological structure of the parathyroid glands. However, due to limited access to the scientific literature at the time, Sandström's work failed to gain international recognition for several more years, and his promising scientific career was interrupted by tragedy. Sandström, who struggled with chronic depression, committed suicide at the age of 37 years [3]. The importance of his research was only recognised a decade later, two years after his death, when Eugène Gley, a French physiologist and endocrinologist, linked the structures identified by the Swedish student to tetany, which was then a common complication of thyroidectomy [5].

## The link between parathyroid glands and tetany and the 'detoxification theory'

The 19th century was a time of rapid development in thyroid surgery. The first attempts to operate on this organ were associated with severe complications and high intraoperative mortality. In the mid 19th century, two prominent surgeons, Theodor Billroth and Emil Theodor Kocher, independently developed techniques that revolutionised thyroid surgery, allowing for a significant improvement in treatment outcomes. However, their success in significantly increasing survival rates after thyroidectomy was associated with previously unknown postoperative complications. Symptoms of hypothyroidism were a common complication in patients operatively treated by Kocher, while many Billroth's patients developed tetany in the first few days post-surgery, usually with fatal outcome [6].

In 1891, Eugène Gley discovered that intraoperative damage to the parathyroid glands led to tetany. He showed in animal experiments that tetany attacks after thyroid surgery occurred only if the excised material included the parathyroid glands, previously described by Sandström. Sparing the parathyroid glands during thyroidectomy prevented tetany. Gley believed that there was a functional relationship between parathyroid glands and the thyroid gland, and only their simultaneous removal induced tetany symptoms. He additionally believed that the parathyroid glands were responsible for the elimination of toxins from the body and proposed a theory that postoperative tetany was caused by toxin accumulation due to detoxification dysfunction of the glands [5]. Although his theory was proven wrong, Gley was the first person to attribute

a vital role to the parathyroid glands, previously considered to be non-functional.

During the same period, Italian surgeons Giulio Vassale and Francesco Generali also conducted research on parathyroid glands. By conducting experiments on cats and dogs, they identified four parathyroid glands in each individual and showed in 1896 that tetany also develops after selective removal of all the parathyroid glands while preserving the thyroid [7]. On this basis, they proved that the parathyroid glands are not part of the thyroid gland, but play a separate role in the body. Despite the lack of scientific evidence, Vassale and Generali supported the 'detoxification' theory proposed by Gley, which was believed for the next 10 years.

**Relationship between tetany and hypocalcaemia**

In 1909, American pathologists William MacCallum and Carl Voegtlin from the Johns Hopkins Hospital demonstrated that tetany is not caused by poisoning, but results from impaired calcium metabolism. They observed that parathyroidectomy in animals caused a decrease in tissue calcium levels and excessive urinary and faecal excretion of this ion, which correlated with the severity of tetany. They then conducted a study in which they administered calcium, sodium and potassium salts to dogs with parathyroidectomy-induced tetany. Of the substances tested, only calcium salts caused symptom alleviation and prevented death in the animals. It was shown based on these observations that the parathyroid glands play a key role in maintaining proper blood calcium levels and that tetany arises from hypocalcaemia caused by insufficient secretory function of these glands [8]. Thus, after 10 years, they resolved the misconception about the detoxifying function of the parathyroid glands.

**The role of the parathyroid glands in bone disease and the 'compensatory hypertrophy theory'**

Brown tumours, which are osseous lesions caused by parathyroid pathology, had been described already before identifying the function of these glands and their role in regulating calcium-phosphate metabolism. In 1891, German pathologist Friedrich Daniel von Recklinghausen published a series of clinical cases of patients with unknown bone disorders. One of these patients presented with typical clinical and pathological features of hyperparathyroidism. The man suffered from multiple painful bone deformities, had a history of multiple pathological poorly healing fractures, and died as a result of complications following femoral shaft fracture. At post-mortem examination, Recklinghausen observed typical signs of bone disease that accompanies hyperparathyroidism, such as generalised fibrosis, bone cysts and brown tumours composed of multinucleated giant cells. He used the term 'osteitis fibrosa cystica' (OFC) [9], today also known as osteitis fibrosa, osteodystrophia fibrosa, and von Recklinghausen's bone disease, due to the morphology of these lesions. Although the disorder is still named after Recklinghausen, he did not see a link between the bone lesions described and parathyroid dysfunction at that time.

It was only a dozen or so years later, when MacCallum and Voegtlin were investigating the relationship between parathyroid glands and tetany, that the Viennese pathologist Jacob Erdheim focused his interest on the correlation between parathyroids and bone disease. In 1906, he noted that rats after parathyroidectomy developed decalcified incisors, which was reversed after reimplantation of the glands [10]. He then conducted post-mortem examinations of deaths due to bone disease, paying particular attention to the parathyroid glands. The glands were found to be significantly enlarged in many patients [11]. Erdheim wrongly concluded that parathyroid hypertrophy was a compensatory phenomenon secondary to primary bone disease, whose role was to increase calcium levels in the affected bone tissue. On this basis, he suggested that gland transplantation and parathyroid extract could be potential therapeutic options for bone disease [11]. Since Erdheim was highly respected in the medical community at the time, his theory was widely accepted and patients with bone disease were inappropriately treated with parathyroid extract for years to come despite the fact that he never provided any scientific evidence to support his theory [12].

**Isolation of parathyroid extract**

The first attempts to treat tetany with a crude extract derived directly from animal parathyroids were made in the first decade of the 20th century; however, not always successfully [13]. The breakthrough is owed to Adolph Hanson and James Collip, who, around the same time, independently developed purified, stable extracts showing efficacy in treating tetany [14].

Adolph Hanson was an American neurosurgeon who, after returning to his hometown after the First World War, set up a private medical practice and built his own laboratory. In 1923, after a series of experiments using bovine parathyroid glands, he independently developed a stable parathyroid extract containing a previously unknown active organic compound, which he named '*hydrochloric X*'. Since further investigations of the isolated substance were impossible under home conditions, Hanson teamed up with the University of North Dakota. He conducted a study in an academic laboratory on dogs treated with *hydrochloric X* within 24 hours of parathyroidectomy. Tetany resolved in all dogs within six hours of administration, and the effect was sustained with subsequent smaller doses of the substance [15]. Following this discovery, Hanson contacted the Eli Lilly pharmaceutical company in 1924 to collaborate on the manufacture of a new tetany drug. However, as an independent researcher working in a home laboratory, he faced rejection. As it later turned out, Eli Lilly was already working with another scientist, James Collip, at that time [14].

James Collip was a professor of biochemistry at the University of Alberta, where he managed a thriving academic laboratory. In 1925, he isolated and purified proteins contained in parathyroid tissue, obtaining an extract he called '*parathyrin*'. Subsequently, like Hanson, he performed a series of successful experiments using parathyrin for parathyroidectomy-induced tetany in

dogs [16]. The extraction methods used by Hanson and Collip were relatively similar. Both researchers treated bovine parathyroid glands with dilute hydrochloric acid, then concentrated the solution by evaporation and titrated until reaching a neutral pH [14]. Since Collip had far greater financial resources and better technical equipment at his disposal, his experiments were more detailed, systematised and involved a significantly larger sample of animals. Although he has gained wider recognition in the scientific community, Adolph Hanson, who through his passion and commitment was the first to independently isolate parathyroid extract, should not be forgotten. Achievements of these two scientists allowed for the production of a stable parathyroid extract on a large scale, resulting in a significant improvement in the treatment of patients with tetany [14]. Following Erdheim's theory of compensatory parathyroid hypertrophy in response to bone disease, parathyroid extract was also used in patients with bone disorders [12].

**Two breakthrough clinical cases of primary hyperparathyroidism**

Following Erdheim's reports on the relationship between the parathyroid glands and bone disease, OFC was considered a primary bone disease. It was not until 20 years later that the actual relationship between these conditions was shown to be quite the opposite, with parathyroid pathology being the primary lesion giving rise to secondary bone damage [12].

Albert Gahne, who was admitted to hospital in Vienna in 1924 and put under the care of surgical resident Felix Mandel due to femoral fracture, was the first patient with documented primary hyperparathyroidism (PHPT). He was diagnosed with OFC during his hospital stay. Following Erdheim's earlier postulates, treatment with parathyroid extract was initiated, and four parathyroids were transplanted from a deceased donor. As the treatment failed, Mandl decided to resect the hypertrophied gland. On 30 July 1925, he removed the left inferior parathyroid gland, measuring 25 × 15 × 12 mm, which he described as yellowish-brown, enlarged, closely adherent to the recurrent laryngeal nerve. The other three parathyroid glands were unremarkable. Postoperatively, the patient's condition improved significantly, with resolution of bone pain and normalisation of serum calcium [17, 18]. Unfortunately, a few years later, the patient experienced a recurrence with symptoms of severe kidney stones. During reoperation, no tumour was found in the neck or the mediastinal region and the man passed in 1936, probably as a result of metastatic parathyroid carcinoma. In addition to bone lesions, postmortem findings included severe bilateral nephrocalcinosis [17, 18]. Mandl was the first to prove that OFC is a disorder secondary to primary parathyroid pathology, and he went down in history as the first surgeon to perform parathyroidectomy for parathyroid tumours.

Over a similar period, PHPT was also diagnosed in an American naval officer, Charles Martell, who also presented with OFC. In 1926, Martell was admitted to Massachusetts General Hospital and put under the care of endocrinologist Joseph Charles Aub, who specialised in calcium metabolism. After many laboratory investigations and consultations, Aub, in cooperation with his colleagues Fuller Albright and Walter Bauer, ultimately diagnosed PHPT and decided to remove the affected glands. Between 1926 and 1931, Captain Martell underwent six neck surgeries, during which two healthy glands were excised. Unfortunately, the affected parathyroid gland was not identified. It was not until 1932 that Edward Churchill, chief of surgery at Johns Hopkins Hospital, in cooperation with resident Oliver Cop, performed a sternotomy in the hope of identifying the affected mediastinal parathyroid gland. During Martell's seventh surgery for hyperparathyroidism and first mediastinal exploration, the surgeons performed a subtotal resection of a 3 × 3 cm mediastinal parathyroid adenoma, which led to an improved patient health status. Unfortunately, six weeks after this successful intervention, Captain Martell developed ureteral obstruction and died due to complications after a urological procedure. The man already had a past history of severe urinary symptoms. Several acute attacks of renal colic and urinary stasis were documented in the course of the disease, with X-ray findings of advanced kidney stones and nephrocalcinosis, as confirmed at post-mortem examination [19, 20].

Over the next few years, more than a dozen other cases of PHPT were correctly diagnosed at Massachusetts General Hospital, marking the beginning of a novel, correct approach to parathyroid physiology and pathophysiology [21, 22].

**The beginning of a novel, correct approach**

Fuller Albright, a prominent endocrinologist who was part of the team of specialists in charge of Captain Charles Martell, devoted almost his entire career to the study of the parathyroid glands, as well as calcium and phosphorus metabolism disorders. His groundbreaking research provided the basis for the development of modern concepts on calcium-phosphate metabolism and parathyroid disease. As a young practitioner, he trained alongside Joseph Charles Aub. It was during this period that Albright was involved in the extensive diagnosis of Captain Martell, who was at that time admitted to Massachusetts General Hospital for the first time. He then did an internship at Johns Hopkins Hospital and spent a year in Vienna, working with Erdheim. In 1929, he returned to Massachusetts General Hospital, where he began his own research. In the years that followed, Albright and his team published extensive papers on calcium and phosphorus metabolism and PHPT, including its pathophysiology, biochemistry, diagnosis, treatment and prognosis [23]. Albright showed that, in addition to its effects on calcium levels, PTH reduces blood phosphorus and increases its excretion in the urine [24]. Furthermore, he was the first to link hyperparathyroidism with kidney stones and nephrocalcinosis. Based on this, he implemented screening for hyperparathyroidism in a group of patients with kidney stones but without bone disease, which contributed to an increase in the number of diagnosed cases [21]. At that time, all parathyroid pathologies presenting with overactive glands were

considered the same clinical entity, i.e. PHPT, which was identified as an isolated adenoma and treated operatively [22, 23]. Albright noted that diffuse hyperplasia of all parathyroid glands rather than just an adenoma of a single gland may underlie hyperparathyroidism [25]. This led him to a conclusion that hyperparathyroidism could have a diverse aetiology. He was the first to accurately describe primary, secondary and tertiary hyperparathyroidism. His findings were summarised in a comprehensive study published in 1948 in the book 'The parathyroid glands and metabolic bone disease' [26].

Albright's research paved the way for further studies at Massachusetts General Hospital, which became a leading centre for the treatment of parathyroid disease and calcium metabolism disorders, with 343 diagnosed cases of hyperparathyroidism between 1930 and 1965. In addition to bone and kidney disease, patients presented with comorbidities such as gastric ulcers, pancreatitis, muscle weakness and hypertension [22].

**Isolation of pure PTH and development of assays for measuring its blood levels**

The importance of a stable form of parathyroid extract became apparent after the first findings of Hanson and Collip were presented [14–16]. Nevertheless, it took another 40 years before a hormone of sufficient purity was developed and its chemical composition determined.

Pure PTH was isolated in 1959 by Howard Rasmussen and Lyman Craig from the Rockefeller Institute in New York. A few years later, in 1962, they described the peptide structure of the hormone [27], for which Craig received the Albert Lasker Prize in 1963 and 29 nominations for the Nobel Prize in Chemistry.

In 1963, Solomon A. Berson and Rosalyn Yalow discovered the antigenic properties of protein hormones and developed an effective radioimmunoassay method for assessing their blood levels, which revolutionised endocrine diagnosis [28]. In 1977, Yalow was awarded the Nobel Prize for this groundbreaking achievement.

**Advances in parathyroid surgery and diagnostic imaging**

Since the first targeted parathyroid tumour resection by Felix Mandel in 1925, parathyroid surgery has evolved towards increasingly less invasive procedures. Initially, wide neck exposure was recommended to visually identify all four parathyroid glands and remove only the involved ones [22].

Advances in laboratory diagnosis resulting from the development of radioimmunoassays to measure PTH have contributed to a significant increase in the number of diagnosed cases of hyperparathyroidism. A population-based study conducted in Rochester (Minnesota) documented a significant increase in the incidence of hyperparathyroidism between 1965 and 1975. The incidence rate increased from 15 to 112 cases per 100,000 population during this period [29]. For this reason, many patients, including those asymptomatic, underwent surgical resection of the glands in the late 1980s [22]. Eventually, uncertainties about the specific indications for surgical treatment arose. Surgery is currently recommended in all symptomatic PHPT cases. It is also advised in asymptomatic patients with serum calcium greater than 1 mg/dL higher than the upper limit of normal, urinary calcium excretion >400 mg/24 h, reduced glomerular filtration rate, kidney stones, osteoporosis and age < 50 years. Secondary and tertiary hyperparathyroidism, on the other hand, is treated conservatively, with parathyroidectomy recommended only in cases of refractory hypercalcaemia, hyperphosphatemia, and severe clinical symptoms [30].

In the 1990s, $^{99m}$Tc-MIBI single-photon emission computed tomography associated with computed tomography scintigraphy (SPECT/CT) was shown to be an effective and precise tool for localising hyperactive parathyroid glands [30, 31]. The use of this preoperative imaging approach in combination with intraoperative measurement of PTH has allowed for gradual reduction of surgical extent [32]. Currently, minimally invasive surgical techniques, endoscopic and videoscopic approaches are preferred. The advantages of minimally invasive surgery include a shorter hospital stay, lower costs, faster recovery and a better postoperative aesthetic outcome [33]. Accurate preoperative imaging is essential for choosing the optimal surgical strategy. Recent years have witnessed significant advances in diagnostic imaging, with increasingly precise and sensitive techniques for preoperative assessment of the parathyroid glands. Ultrasound combined with $^{99m}$Tc-MIBI SPECT/CT scintigraphy is currently a preferred approach for localising pathological parathyroid tissue. These techniques are highly sensitive in cases when hyperparathyroidism arises from a single adenoma. However, their sensitivity decreases in the case of multiple or ectopic parathyroid pathologies. Positron emission tomography/computed tomography (PET/CT), four-dimensional computed tomography (4D-CT), and magnetic resonance imaging (MRI) are imaging techniques offering better localisation in some situations. [$^{18}$F]-fluorocholine PET/CT ([$^{11}$F]-FCH PET/CT) showed nearly 100% efficiency in imaging hyperfunctioning parathyroid glands [34]. In turn, a large study in 19 patients with tertiary hyperparathyroidism treated with renal replacement therapy showed high efficiency of [$^{11}$C]-methionine PET/CT ([$^{11}$C]-MET PET/CT)[35]. Due to their low invasiveness and high efficiency in imaging hyperactive parathyroid glands, PET/CT are leading diagnostic localisation tools. Selective venous sampling (SVS) to assess blood PTH levels is indicated in patients with persistent or neoplastic hyperparathyroidism, in whom imaging methods failed to locate the lesions. There is ongoing research investigating novel approaches, such as robotic surgery or intraoperative imaging techniques, which in the future may contribute to even greater improvement in the management of patients with parathyroid disease.

Our home centre also holds a place in the history of parathyroid glands, where several innovative procedures of selective embolization of parathyroid arter-

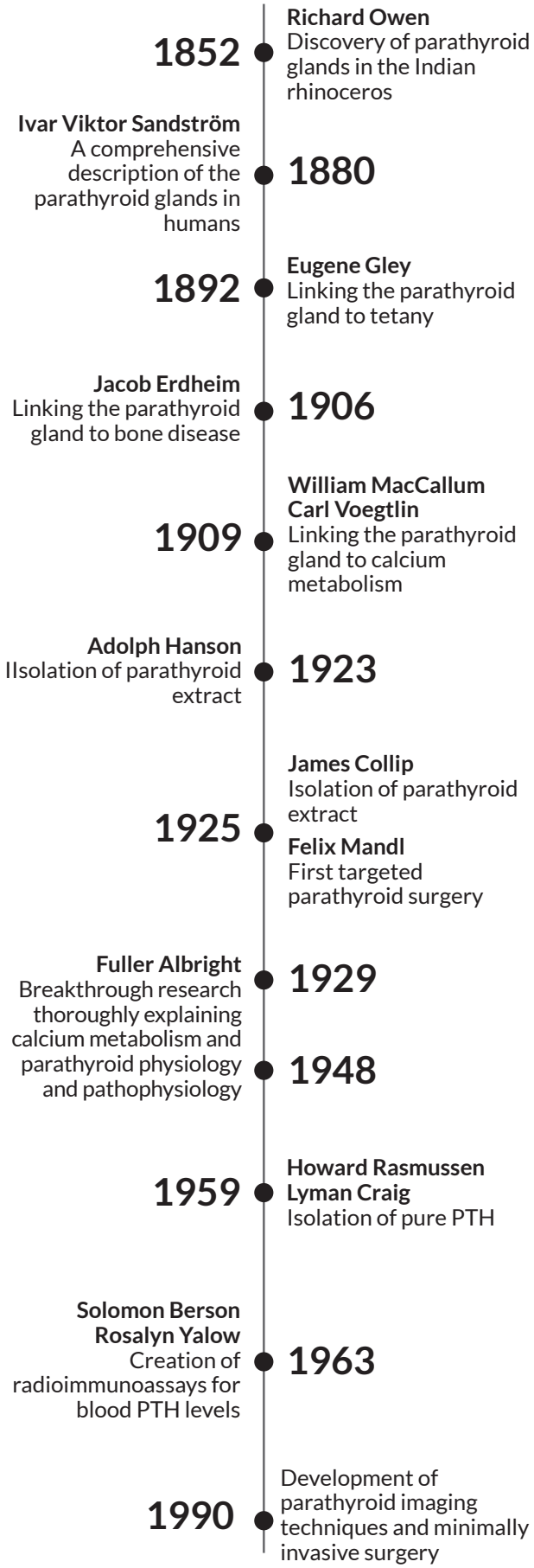


**Figure 1.** Timeline showing key events in the history of parathyroid research development

ies supplying parathyroid adenoma have recently been performed, with good clinical outcomes. Long-term outcomes and an assessment of the efficacy of this minimally invasive method are still awaited.

## Conclusions

The endocrinology of the parathyroid glands developed slowly throughout the 19th and 20th centuries, creating a fascinating history that involved many prominent scientists (fig. 1). Owen, Sandström, Gley, MacCallum, Voegtlin, Erdheim, Hanson, Collip, Mandl, Albright, Craig, and Yalow are just a few of those who contributed to advances in the knowledge of the anatomy, physiology, biochemistry, and surgery of the parathyroid glands. Their groundbreaking discoveries shaped our modern understanding of these glands and contributed to the development of effective diagnostic and therapeutic approaches for the management of disorders arising from their dysfunction.

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REVIEW ARTICLE

# THE EFFECTS OF VITAMIN D LEVELS AND SUPPLEMENTATION ON ORAL HEALTH – REVIEW

## Wpływ stężenia witaminy D i jej suplementacji na stan zdrowia jamy ustnej – przegląd literatury

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**Abstract**

**Introduction:** Vitamin D plays a crucial role in many biological processes, such as regulating calcium-phosphate metabolism, enhancing immune response, and stimulating the mineralization of hard tissues. Vitamin D deficiency affects up to 30% of children in developed countries, especially during the autumn-winter period. In the context of dentistry, reduced vitamin D levels are associated with increased caries activity, including severe early childhood caries. **Materials and methods:** A literature review was conducted using the PubMed database. The analysed studies assessed diverse populations in terms of age, geographical location, and socioeconomic status. **Results:** The optimal level of vitamin D is considered to be at least 75 nmol/L. Vitamin D deficiency is associated with various systemic diseases, including dental caries. Children with severe early childhood caries have lower levels of vitamin D, which increases their susceptibility to caries. Adequate vitamin D levels promote enamel mineralization, increase salivary flow, and salivary calcium content, which protect against cariogenic microorganisms. There is also evidence linking maternal vitamin D levels and the risk of caries in their children. **Conclusions:** Vitamin D plays a crucial role in the prevention and treatment of dental caries, especially in children. Promoting vitamin D supplementation, according to Polish guidelines, can significantly reduce the risk of caries. Research on genetic polymorphisms opens new perspectives for the individualization of caries prevention strategies. Monitoring vitamin D levels in expectant mothers can also contribute to reducing the risk of caries in their offspring. Further research is needed to better understand the mechanisms of vitamin D impact on oral health and to develop detailed recommendations for supplementation.

**Streszczenie**

**Wstęp:** Witamina D odgrywa główną rolę w wielu procesach biologicznych, w tym w regulacji gospodarki wapniowo-fosforanowej, wzmacnianiu odpowiedzi immunologicznej i stymulacji mineralizacji tkanek twardych. Niedobór witaminy D dotyczy nawet 30% dzieci w krajach rozwiniętych i występuje zwłaszcza w okresie jesienno-zimowym. Obniżone stężenie witaminy D jest powiązane m.in. ze zwiększoną aktywnością próchnicy, w tym ciężką postacią próchnicy wczesnego dzieciństwa. **Materiały i metody:** Przegląd literatury przeprowadzono z wykorzystaniem bazy danych PubMed. Analizowane prace obejmowały badania różnych pod względem wieku, szerokości geograficznej i statusu socjoekonomicznego grup. **Wyniki:** Za optymalne stężenie witaminy D uznaje się co najmniej 75 nmol/l. Jej niedobory są powiązane z wieloma schorzeniami ogólnoustrojowymi, w tym z próchnicą zębów. U dzieci z próchnicą wczesnego dzieciństwa obserwuje się niższe stężenie witaminy D, co zwiększa ich podatność na próchnicę. Odpowiednie stężenie witaminy D wpływa korzystnie na mineralizację szkliwa oraz zwiększa wydzielanie śliny i zawartość wapnia, co chroni przed działaniem kariogennych mikroorganizmów. Istnieją również dowody na wpływ stężenia witaminy D u matek na ryzyko wystąpienia próchnicy u ich dzieci. **Wnioski:** Witamina D odgrywa kluczową rolę w prewencji i leczeniu próchnicy zębów, zwłaszcza u dzieci. Promowanie suplementacji witaminy D, zgodnie z polskimi wytycznymi, może znacząco zmniejszyć ryzyko wystąpienia tej choroby. Badania nad polimorfizmami genowymi otwierają nowe perspektywy dla indywidualizacji profilaktyki próchnicy. Monitorowanie stężenia witaminy D u przyszłych matek może również przyczynić się do zmniejszenia ryzyka rozwoju próchnicy u ich potomstwa. Konieczne są dalsze badania, aby lepiej zrozumieć mechanizmy wpływu witaminy D na zdrowie jamy ustnej i opracować szczegółowe rekomendacje dotyczące suplementacji.

**Keywords:** dental caries; vitamin D; calcitriol; supplementation; early childhood caries

**Słowa kluczowe:** próchnica zębów; witamina D; kalcytriol; suplementacja; próchnica wczesnego dzieciństwa

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## Introduction

It is estimated that vitamin D deficiency may affect up to 30% of children in developed countries (depending on the definition), especially during the autumn/winter period [1]. 25OHD (25-hydroxycholecalciferol) is the main circulating vitamin D metabolite [2], whose serum level is the best indicator of vitamin D deficiency [3]. In the kidneys, it undergoes hydroxylation to the active form of vitamin D, i.e. 1,25-dihydroxycholecalciferol (calcitriol) [3]. Vitamin D receptors are expressed across many tissues, which translates into a wide variety of functions of this compound [1].

Known properties of vitamin D include enhancing the antimicrobial response of the body [4], regulating calcium-phosphate metabolism by increasing calcium uptake in the small bowel [5], protecting against autoimmune disorders and even malignancies through antiproliferative properties [6], and stimulating mineralisation of hard tissues [5]. It has been shown that calcitriol deficiency can lead, among other things, to cardiovascular, respiratory and nervous system disorders.

Many studies indicate a link between reduced vitamin D levels in children and increased activity of dental caries [1,2,4], including severe early childhood caries (SECC) [4], defined as any sign of smooth-surface caries in a child younger than three years of age [4]. SECC is estimated to affect up to 621 million children worldwide, ranging from 11.7% in the UK to 41.1% in Poland, and up to 46.8% in the US [4].

The aim of this study was to explore and discuss the problem and to shed a broader light on the abundant evidence linking tooth decay with reduced vitamin D levels in order to raise awareness among dentists and the public.

## Materials and methods

The data presented were obtained from the PubMed database. The cited papers discuss studies conducted in different countries on several continents in populations that varied in terms of age, latitude inhabited and socioeconomic status.

## Results

*The impact of vitamin D on the human body*

A vitamin D level of ≥75 nmol/L is most often considered optimal [2, 5, 7,]. Some authors propose a broader classification, distinguishing insufficiency (50–74.9 nmol/L), deficiency (25–49.9 nmol/L) and severe deficiency (<25 nmol/L) in addition to normal levels (>75 nmol/L) [8]. Vitamin D deficiency is also classified as low (<50 nmol/L), moderate (<25 nmol/L) and severe (<12.5 nmol/L), with the latter two groups considered by the authors to be the cause of rickets, osteoporosis and osteomalacia [9]. Up to one billion people, both children and adults, have vitamin D deficiency defined as <25 nmol/L [10]. The terminology and classification of vitamin D deficiency is presented in table 1 [7].

*Vitamin D deficiency and oral health*

In addition to systemic conditions, many papers point out that vitamin D deficiency is highly related to dental caries [1–4].

Early childhood caries (ECC), defined as presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries) or filled tooth surfaces in any primary tooth in a child 71 months of age or younger, has been particularly linked to vitamin D deficiency [11]. Severe early childhood caries (SECC) is defined as any sign of smooth-surface caries in a child younger than three years of age [4]. Children with SECC have lower vitamin D levels [2, 8, 12] and are twice as likely to have vitamin D values <75 nmol/L [2]. Statistically, caries-free children are twice as likely to have normal calcidiol levels, whereas children with SECC are three times more likely to present with levels <35 nmol/L. Increased salivary flow and high salivary calcium content [2], as well as increased mineralisation of enamel and dentin, protection against hypoplasia and hypomineralisation leading to reduced teeth susceptibility to cariogenic microorganisms, are known mechanisms of action of vitamin D [5, 13]. Additionally, adequate vitamin D levels have a positive impact on salivary cathelicidin LL-37 [14]. Cathelicidin LL-37 is an antimicrobial peptide composed of 37 amino acids, produced via proteolytic degradation of the extracellular domain of hCAP-18, a protein expressed in epithelial cells and neutrophils [14], which shows activity against *S. mutans* [4]. Furthermore, calcitriol increases the intestinal uptake of calcium (by 40%) and phosphate (by up to 80%) [15]. It was also shown that ECC children are more likely to develop malnutrition and anaemia [15], while SECC children have higher parathyroid hormone levels and lower serum calcium levels [12].

**Table 1.** Classification of vitamin D deficiency [7]

| Plasma vitamin D level [nmol/L] | Grade |
|---|---|
| **<25** | Severe deficiency |
| **25–50** | Moderate deficiency |
| **50–75** | Sufficient level |
| **75–200** | Normal level |

There also appears to be a link between maternal prenatal vitamin D levels and the risk of caries in the child [16–19]. Mineralisation of deciduous and permanent enamel occurs at 4 months gestation and after birth, respectively [16]. Alaskan researchers, Singleton et al. [17], demonstrated a 40% increase in DMFT (number of decayed, missing or filled teeth) in 12–35-month-old children whose mothers had low vitamin D levels at 36 weeks gestation compared to children whose mothers had normal vitamin D levels. Beckett et al. [16] found an increased risk of caries in 6-year-old children whose mothers had vitamin D levels at third trimester of <50 nmol/L. Additionally, based on dental reviews of 1210 mother-child pairs, Tanaka et al. [20] found a negative correlation between the incidence of caries in the child and maternal intake of vitamin D. There is also evidence of an association between maternal calcidiol levels in the second trimester and the incidence of molar incisor hypomineralisation (MIH) in the child at the age of 7–9 years [18]. Lower vitamin D levels were also observed in mothers of children with deciduous molar hypomineralisation (DMH), diagnosed by digital microscopy [19]. Furthermore, it was shown that high-dose vitamin D supplementation in pregnancy can reduce the child's risk of enamel defects, such as opacity and chipping, by up to 50% [21].

A reference should be also made to studies that do not confirm the correlation between calcidiol levels and the risk of ECC [21-23], but indicate a relationship between salivary and serum levels of vitamin D [22], as well as papers presenting inconclusive results and suggesting the need for further research [24]. There have also been reports that negate the association with maternal vitamin D levels, while confirming that there is a twofold decrease in DMF in children with normal calcidiol levels compared to those with deficiency [25].

*The impact of geographical latitude on vitamin D levels and the need for supplementation*

Inhabitants of regions above the 37th parallel (including Poland), where the efficiency of endogenous vitamin D synthesis decreases between November and February due to lower UVB exposure, are at risk of vitamin D deficiency, and therefore the importance of vitamin D supplementation throughout the year is emphasised in this group [26]. Kuciński et al. [26] developed guidelines for vitamin D supplementation in the Polish population at different life stages. They suggested vitamin D supplementation at a dose of 400 IU per day from birth to 6 months of age, and then at 600 IU per day to 12 months of age. The dose is 600 IU per day for children from 1 to 3 years of age and 600–1000 IU per day from 4 to 10 years. Sunlight exposure for 30–45 minutes per day between 10 a.m. and 3 p.m., between the beginning of May and the end of September, is also recommended in this age group. Adolescents and adults up to 65 years of age should receive a daily dose of 1000 to 2000 IU, with sunlight exposure for 15–30 minutes. Individuals up to 75 years of age are recommended to continue the same dose throughout the year without additional exposure to sunlight. Due to their reduced ability to synthesise cholecalciferol in the skin, seniors >75 years of age should supplement vitamin D at a daily dose of 2000-4000 IU throughout the year. It is suggested that cholecalciferol be first choice, with calcifediol used as the second choice [26] (tab. 2).

As pointed out by Sobiech et al. [2], vitamin D supplementation during the autumn-winter period in Poland is associated with a twofold reduction in the risk of caries exacerbation in children ≥12 years of age. Hujoel et al. [27] have shown that supplementation reduced the risk of caries in children by 47%, but that this effect was no longer evident after the age of 13 years, especially in girls, which the authors explain by an increase in body fat. In their study in a population of 10-year-olds in Germany, Kühnisch et al. [28] showed a twofold decrease in the incidence of dental caries in children supplemented with vitamin D in their first year of life. However, these preparations were less effective than fluoride-containing supplements (OR = 2.08 for vitamin D and 2.47 for fluoride).

Obviously, dental caries is not the only problem against which vitamin D offers potential protection [10, 13]. Daily supplementation continued for 3 years can reduce the risk of tooth loss due to periodontitis by 60% [29]. As shown by Zhan et al. [23] in their study conducted among 1904 Germans over a 5-year period, a 10 µg/L increase in calcidiol reduced the risk of tooth loss by 13%. However, this issue remains open as not all studies have confirmed such a relationship [30].

*Vitamin D and genetic predispositions*

The influence of genetic factors on the action of vitamin D in the body is an interesting aspect. Gene polymorphisms are defined as variants of a given gene occurring in the population with a frequency greater than 1%, which distinguishes them from genetic mutations [31]. Rapid advances in knowledge and technology have allowed scientists to identify a clear link between active caries and the T allele of rs2228570 (FokI) polymorphism related to one of the nucleotides that make up the vitamin D receptor

**Table 2.** Vitamin D supplementation guidelines by Kuciński et al. [26]

| Population | Recommended vitamin D supplementation (IU/day) |
|---|---|
| Newborns and infants up to 6 months of age | 400 |
| Infants 6–12 months of age | 400–600 |
| Children 4–10 years of age | 600–1000 |
| Adolescents | 1000–2000 |
| Adults 19–65 years of age and younger seniors 66–75 years of age | 1000–2000 |
| Seniors >75 years of age | 2000–4000 |

gene. In contrast, subjects with the C allele were more likely to be caries-free [31, 32]. However, this issue is not clear as Cogulu et al. [33] obtained a statistically significant correlation only for the TaqI polymorphism, while they found no significant difference in the prevalence of ApaI, FokI and Cdx2 polymorphisms between caries- and caries-free population. Izakovicova Holla et al. [34], on the other hand, showed no link between caries and TaqI polymorphisms, but observed a significant correlation between TaqI and gingivitis.

## Discussion

The research presented here indicates an indisputable role of vitamin D in the prevention and treatment of dental caries, including SECC. Findings on the relationship between vitamin D deficiency and increased dental caries highlight the importance of vitamin D levels for oral health. The cited research indicates that SECC children have lower vitamin D levels compared to their caries-free peers, suggesting that adequate vitamin D levels may protect against the development of this disorder [1, 2, 4].

It is also worth mentioning about the mechanisms by which vitamin D exerts its beneficial effects on oral health. These include increasing salivary flow and salivary calcium content, which promotes enamel and dentin mineralisation. Additionally, by improving gastrointestinal uptake of calcium and phosphate, calcitriol reinforces tooth structure and contributes to better protection against cariogenic bacteria [2, 8, 13–15].

Also of interest is the evidence for the association between maternal prenatal vitamin D levels and the risk of caries in the child. Research highlights the importance of adequate vitamin D levels from the earliest stages of life, pointing to the possibility of preventing dental disease through dietary interventions and supplementation in pregnancy [16–19].

Despite this considerable evidence, there are also studies that do not support the direct relationship between vitamin D levels and the risk of ECC [21, 22, 32]. This indicates the complexity of dental caries and the need for further research to better understand the role of vitamin D in the prevention of this disease.

When discussing supplementation guidelines, it is important to emphasise that adequate vitamin D intake is important not only for caries prevention, but also for overall health. Recommendations for supplementation, especially in regions with limited sunlight, are crucial to improve vitamin D status in the population, which may help reduce the incidence of caries, especially among children [26].

Research on gene polymorphisms affecting calcitriol activity in the body is also important. These findings open up new perspectives for the individualisation of preventive and therapeutic approaches to dental caries, based on the genetic predisposition of patients [31, 32].

The analysis of the cited studies indicates that further research is needed to better understand the impact of vitamin D on oral health, so that specific recommendations for its supplementation can be made. Although maintaining optimal vitamin D levels can significantly contribute to oral health and caries prevention, individual needs and genetic differences in the population need to be considered.

## Conclusions

In conclusion, vitamin D plays an important role in the prevention of caries, including severe early childhood caries. The association between low vitamin D levels and increased caries activity indicates the need to promote vitamin D supplementation as an effective form of prophylaxis. Polish guidelines on vitamin D supplementation emphasise its important role at different stages of life, which may be crucial in reducing the risk of caries.

Additionally, research on gene polymorphisms indicates that an individualised approach to caries prevention taking into account the genetic determinants of the body's response to vitamin D may be possible. It is likely that such an approach will increase the efficacy of caries prevention, particularly in individuals with specific genetic factors.

Attention has also been drawn to the importance of monitoring vitamin D levels in expectant mothers, which can reduce the risk of their offspring developing caries, pointing to the importance of maintaining adequate levels of this vitamin already from the prenatal period.

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# SHAPING THE PROPERTIES OF THE AEROSOL CLOUD OF NEBULIZING DRUGS. PART I. THEORETICAL BACKGROUND

## Kształtowanie właściwości chmury aerozolowej leków nebulizacyjnych. Część I. Podstawy teoretyczne

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**Abstract**

The paper presents basic data on various types of nebulizers and indications for nebulization. We discuss the most commonly assessed parameters of the aerosol cloud and factors influencing the efficacy of nebulization, emphasizing the relationship between the characteristics of the inhaled aerosol agents (budesonide, salbutamol) and both the site of their deposition in the respiratory tract and their clinical effect.

**Streszczenie**

W pracy przedstawiono podstawowe dane dotyczące różnego rodzaju nebulizatorów oraz wskazań do nebulizacji. Przypomniano najczęściej oceniane parametry chmury aerozolowej i omówiono czynniki wpływające na efektywność nebulizacji. Podkreślono związek między charakterystyką chmury aerozolowej inhalowanych leków (budezonid, salbutamol) a miejscem ich depozycji w drogach oddechowych i efektem klinicznym.

**Keywords:** budesonide; nebulization; jet nebulizer; MMAD; lung deposition

**Słowa kluczowe:** budezonid; nebulizacja; nebulizator pneumatyczny; MMAD; depozycja w drogach oddechowych

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### Introduction

The aim of this study was to demonstrate the rationale behind and the possibility of influencing the physical properties of an aerosol cloud of selected nebulized agents to improve their targeted deposition in the airways, and thereby optimise clinical outcomes and safety. To this end, we reviewed the literature available in the PubMed database and studies done by nebulizer manufacturers on the background of our own research. The research comprised two parts: theoretical and practical.

Nebulization is a type of inhalation therapy using a device (nebulizer) that generates an aerosol by mechanically dispersing (atomising) a liquid drug (solution or suspension) [1, 2]. There are several classes of nebulisers, differing in their mechanism of liquid dispersion, with pneumatic nebulisers (PNs) and ultrasonic nebulisers (classic and ultrasonic mesh nebulizers [MNs]) representing the two main classes (fig. 1).

Nebulization is recommended for the treatment of laryngitis/tracheitis, asthma, obstructive bronchitis in children, bronchitis (both recurrent and chronic), chronic obstructive pulmonary disease, cystic fibrosis, bronchiectasis, primary ciliary dyskinesia, bronchiolitis, neonatal respiratory distress syndrome, bronchopulmonary dysplasia, pulmonary hypertension, pneumonia in immunocompromised patients, as well as in the prevention of ventilator-associated pneumonia [3, 4]. Glucocorticoids s (GCs) (budesonide, fluticasone propionate), short-acting beta$_2$-agonists (salbutamol, fenoterol), short-acting muscarinic receptor

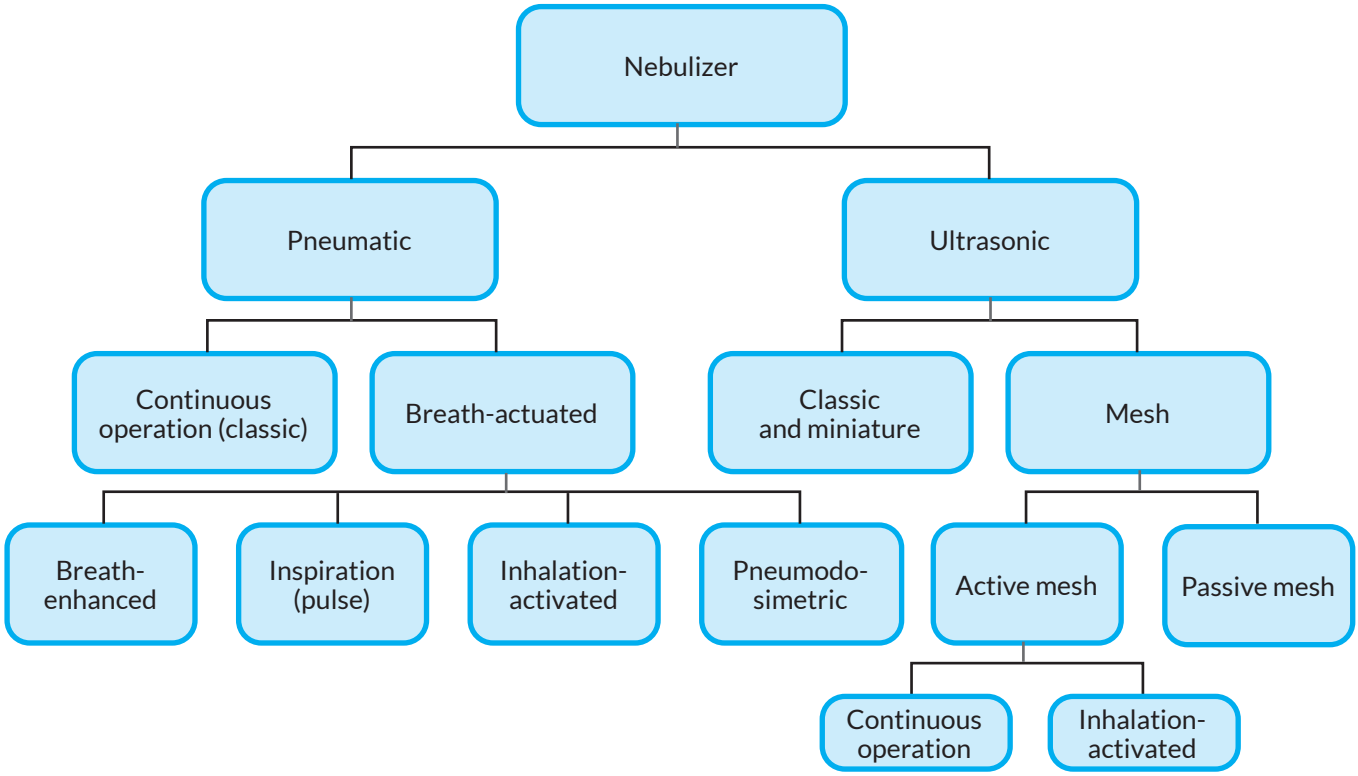


**Figure 1.** Types of nebulisers [1, 3]

agonist (ipratropium bromide), antibiotics (colistin, tobramycin, aztreonam, amphotericin B), saline solutions, mucoactive agents (e.g. ambroxol), dornase alfa, iloprost, surfactants, and opioids are the most commonly used nebulized agents in Poland. There is also a relatively large group of nebulized drugs not available in our country, such as epinephrine, terbutaline, formoterol, levofloxacin, pentamidine, insulin, and some antibiotics [5].

The properties of the drug itself (dose, formulation) and the inhaler, the characteristics of the patient (age, type of pathology), and the inhalation technique are the main factors determining the clinical efficacy and safety of inhalation therapy, including nebulization [6]. In clinical practice, the choice of drug and nebuliser should primarily depend on the type of pathology and the involved airway region, as this is where the inhaled substance will be delivered and deposited [7–9].

**Aerosol cloud characteristics and assessment methods**

The aerosol cloud leaving any inhaler (including a nebuliser) may be described by several parameters that provide important information about the characteristics (quality) of the therapeutic aerosol. The most commonly used parameters include [2, 3, 9]:

- mass median aerodynamic diameter (MMAD) – aerodynamic diameter of a particle (μm) or a nebulized droplet (when liquid is sprayed), corresponding to the median mass distribution. This parameter provides data on the average particle/droplet size in a given aerosol, or more precisely, in the inhaled portion of aerosol. The smaller the MMAD, the smaller the particles/droplets, and therefore the greater the likelihood that the drug will deposit in the lower airways;
- fine particle fraction (FPF) – the proportion of fine particles/droplets, i.e. with an aerodynamic diameter <5 μm. The higher the FPF value, the higher the amount of drug that reaches the lower airways, and the higher the fine particle dose (FPD);
- geometric standard deviation (GSD) – a measure (a dimensionless value) of the particle/droplet size distribution in a given aerosol with a lognormal distribution (typical for nebulized aerosols). Monodisperse aerosols, i.e. composed of particles of similar size (GSD <1.2), and polydisperse aerosols, which contain particles of different sizes (GSD >1.2) have been distinguished.

These parameters are conventionally assessed using an Andersen cascade impactor or a Next Generation impactor [10]. For nebulized aerosols, it is convenient and reasonable to use optical methods, including laser diffraction [11]. The method involves determining, among other things, Dv50 (μm), also known as volume median diameter (VMD), i.e. the median distribution relative to the volume of droplets in the total aerosol leaving the nebulizer [12, 13]. Other percentile values of aerosol droplet size distribution are also often determined, such as Dv10 (with 10% of droplets smaller than this value) and Dv90 (with 90% of droplets smaller than this value), as well as Span = Dv50/(Dv90–Dv10), which is a measure of the polydispersity of droplets in the cloud, yet more universal than GSD as it is also used for non-lognormal distributions [12]. It is worth highlighting a certain difference between MMAD and Dv50 (VMD). MMAD is estimated for aerosol that can enter the airways, as it is determined for aerosol deposited in the cascade impactor. Thus, it does not include the largest aerosol particles. In comparison, Dv50 informs about the total nebulized cloud (i.e. all-size droplets) [12]. There-

fore, Dv50 equals MMAD only if all nebulized droplets are smaller than approx. 10 µm [14, 15].

### Airway aerosol deposition and clinical outcomes

The properties of aerosol cloud, FPF, MMAD and GSD in particular, are the most important factors determining the site, extent and mechanisms of drug deposition in the airways [16] (tab. 1).

Inhalation technique used by the patient is another important aspect [18]. If nebulized aerosol shows monodisperse characteristics (GSD <1.2), its site of deposition in a given airway region is more predictable, and the therapy becomes more targeted [19, 20]. Given the deposition mechanisms of aerosol particles in the airways, there is a range of particle sizes that will not be properly deposited in any part of the airways, but will be expelled in exhalation instead. Therefore, 0.3–0.7 µm particles/droplets may be considered therapeutically useless; however, these account for a negligible proportion of total nebulized aerosol [16].

*In vitro* and *in vivo* studies indicate a close correlation between the size of particles produced by different inhalers and the extent and site of pulmonary deposition of different drugs. Large particles (>5 µm) tend to deposit mainly in the upper and large airways, limiting the amount of aerosol that can be delivered to the peripheral lungs. Fine particles (2–5 µm) mainly deposit in the central and small airways, whereas ultrafine particles (<2 µm) tend to deposit in the alveolar region [18, 21–25].

Acute laryngitis in children or adults and acute bronchiolitis in children are good examples. In patients with laryngitis, GCs should deposit mainly in the larynx, which will be highly effective with an aerosol cloud with an average particle size of 8–10 µm and short, forceful inhalations during nebulization to increase inertial deposition of the aerosol in this region [26]. In the case of acute bronchiolitis, a common infection in children <3 years of age, GCs or short-acting beta$_2$-agonists with the lowest possible MMAD (<2.0 µm) should be used, with breathing rate as low as possible [27].

The relationship between aerosol cloud structure, inspiratory flow rate and clinical outcome was best documented by Usmani et al. for monodisperse salbutamol [28]. They demonstrated that asthmatic patients showed greater improvement in forced expiratory volume in 1 second ($FEV_1$) after slow inhalation of 6 µm salbutamol particles vs. rapid inhalation of 3.0 or 1.5 µm particles.

### Different nebulisers, different aerosol clouds

Nebulisers produce aerosol clouds with highly variable parameters. This is due to the type and technical characteristics of the device (PNs vs. MNs) and the type and formulation of the drug (solution/suspension physicochemical properties) [29, 30]. It was already more than 10 years ago when Pirozynski et al. showed that 0.9% NaCl solution produced by the various PNs available at that time in our country had MMAD ranging from 1.8 to 4.5 µm [31]. Hatley et al. demonstrated that the parameters of the salbutamol aerosol cloud from 9 different nebulisers could differ by up to twofold, particularly among PNs [29] (tab. *2*).

The same phenomenon was demonstrated by Sosnowski et al. for budesonide aerosol generated by three different MNs [32]. The multiple factors determining the efficacy and safety of nebulization in children and adults are illustrated with an example of budesonide in figure 2.

### Conclusions

Nebulization is a commonly used form of aerosol therapy for acute and chronic airway conditions in both children and adults. This paper presents the rationale behind and theoretical background for the possible impact on the physical properties of the aerosol cloud of selected nebulized agents to improve their targeted deposition in the airways. The clinical effect and safety of a nebulised drug depend on the type of nebuliser used, the properties and dose of the drug administered and the way the patient inhales the aerosol. Achieving an optimal clinical effect of nebulization therapy is only possible if all the above-mentioned considerations are properly taken into account.

**Table 1.** Particle size of medical aerosols and site of their deposition in the airways [17, 18]

| Fraction | MMAD [µm] | Primary deposition site |
|---|---|---|
| **Therapeutic aerosol** | <10 | larynx, trachea, bronchi, bronchioles |
| **Fine particles** | <5 | bronchi, bronchioles, alveoli |
| **Ultrafine particles** | <1,5 | bronchioles, alveoli |
| MMAD – Mass Median Aerodynamic Diameter (particle size of medical aerosols) | | |

**Table 2.** Characteristics of salbutamol aerosol cloud produced by different PNs and MNs [29]

| Type od nebuliser | VMD (µm) min–max | FPD (% DN) min–max |
|---|---|---|
| **Pneumatic nebulisers** | 3,27–7,35 | 30,1–73,1 |
| **Ultrasonic mesh nebulisers** | 4,44–5,04 | 50,3–59,9 |
| FPD – fine particle dose; DN – nominal dose; VMD (volumetric median diameter volumetric) – diameter corresponding to the median droplet size distribution | | |

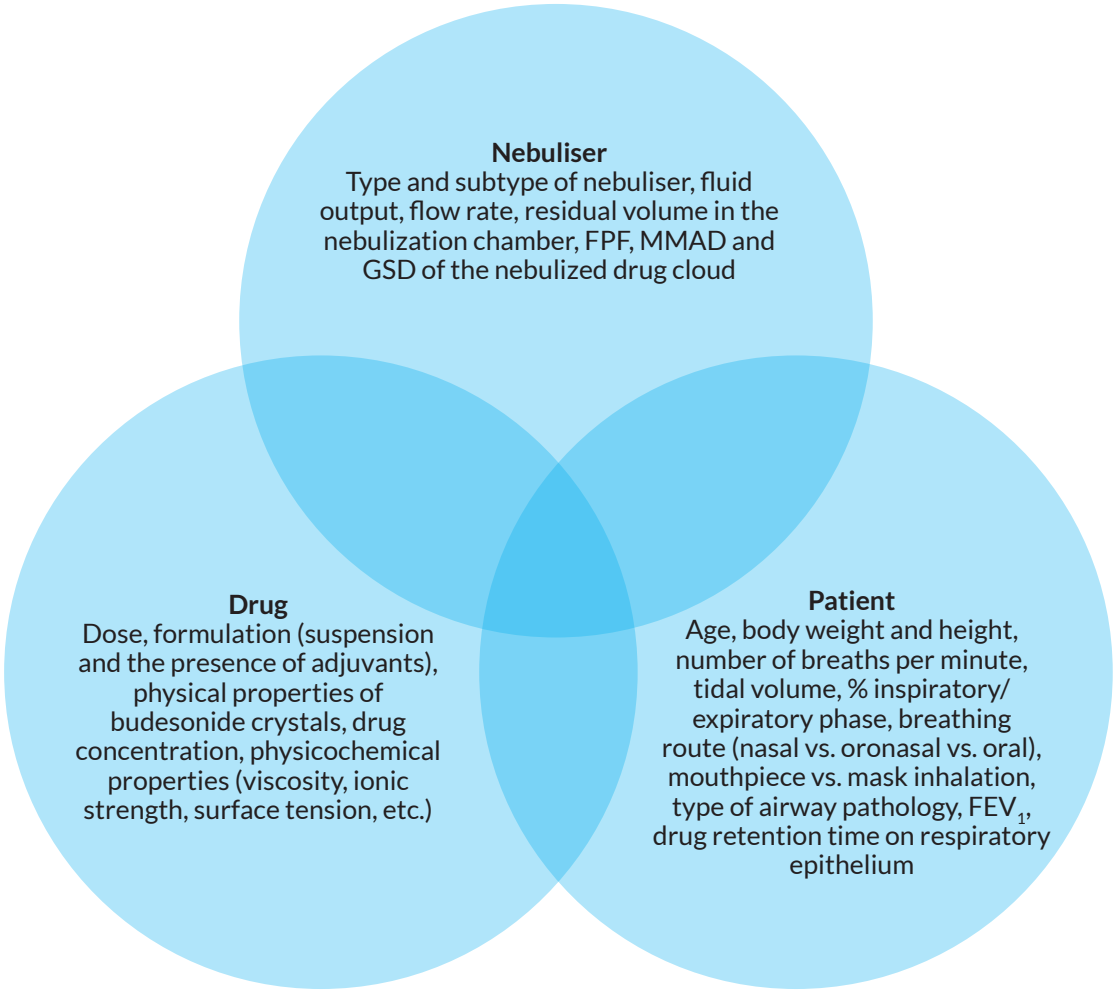


**Figure 2.** Factors influencing the clinical efficacy and safety of nebulised budesonide [30, 33-37]. FPF – fine particle/droplet fraction; MMAD – mass median aerodynamic diameter used for defining particle size distribution; GSD – geometric standard deviation

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REVIEW ARTICLE

# MANAGING THE COST OF SERVICES FOR PEOPLE WITH DISABILITIES: AN INTERNATIONAL APPROACH. PART I: POLAND

## Zarządzanie wydatkami na opiekę osób z niepełnosprawnościami. Podejście międzynarodowe. Część I: Polska

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**Abstract**

**Introduction:** The cost of care for people with disabilities is rising, whereas all forms of support for them are decreasing. Countries and communities develop different ways to serve the disabled. We examined the comprehensive state of care from the perspective of cost management of services for individuals with disabilities in Poland. **Method:** This paper is based on a review of relevant international literature, with a special focus on the situation in Poland. A keyword search was completed in both Polish- and English-language databases. **Results:** In Poland, people with disabilities usually live with their families, and specialized services are offered outside the place of residence. Community and privately-owned housing resembling family homes is being developed. However, for many families with disabled members, such an option is unaffordable. **Discussion:** New policy programs are being developed to protect, care for, and support people with disabilities in Poland. However, some of these policies have not been implemented due to limited financial resources. Overall, the development of health care services offered in places where individuals with disabilities live improves their quality of life but also increases the costs of care.

**Streszczenie**

**Wstęp:** Zarządzanie wydatkami na opiekę osób z niepełnosprawnościami staje się coraz bardziej utrudnione ze względu na wzrost cen i zmniejszający się wybór usług. W wielu środowiskach i krajach wypracowywane są różne optymalne metody wsparcia grup wymagających opieki. W tej pracy postanowiliśmy przedstawić system opieki osób z niepełnosprawnościami w Polsce. **Metoda:** Artykuł powstał w oparciu o przegląd odpowiedniej literatury międzynarodowej, ze szczególnym uwzględnieniem sytuacji w Polsce. Przeprowadzono wyszukiwanie słów kluczowych w bazach danych w języku polskim i angielskim. **Wyniki:** W Polsce osoby niepełnosprawne zazwyczaj mieszkają z rodziną, a specjalistyczne usługi świadczone są poza miejscem zamieszkania. Tworzy się budownictwo komunalne i prywatne na wzór domu rodzinnego. Dla wielu rodzin żyjących z niepełnosprawnymi członkami rodziny taki wybór nie jest możliwy, ponieważ jest zbyt kosztowny. **Dyskusja:** W Polsce powstają nowe przepisy prawne normujące zasady pomocy dla osób z niepełnosprawnościami i przyznające niezbędne usługi. Jednak pomimo dobrych przepisów gwarantujących poprawę warunków życiowych, ich zastosowanie często sprawia trudności ze względu na cenę i dostępność usług.

**Keywords:** housing; services; financial management; social work; residential care

**Słowa kluczowe:** domy opieki; usługi; zarządzanie finansami; mieszkanie; praca socjalna

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## Introduction

Since 2020, we have observed monumental changes in our world within a very brief period. As with any global event, we reevaluated our values, goals, and resources after COVID-19. In addition to the accelerated transformation of our personal and professional lives, there are also slow but substantial changes, like the aging of society and the rising cost of living. These two kinds of phenomena, fast and slow, have opposing effects on people's lives. On the one hand, we have learned to value our quality of life; on the other, we are forced to limit spending. The goal of adjusting to this new reality is to improve financial management with a focus on enhancing quality of life. This article presents our findings on how social workers, internationally and specifically in Poland, are striving to achieve this adjustment in a changing world. We understand that improving quality of life requires a better understanding of the often-dynamic needs of our clients, as well as the needs of those who provide our clients with necessary care and services, some of which are, predictably, economic in nature.

An aging society is a significant global phenomenon. With aging, there is an increase in the number of people who depend on the financial resources of a younger population that, by contrast, is declining in numbers. This smaller group faces a comparatively higher cost of living and has obligations to preceding generations that now expect their care. Among those aging populations are people with deteriorating health and neurocognitive disorders, which further increases the already significant number of people with disabilities [1, 2].

With recent progress in medicine and science, we have gained a deeper understanding of the specific needs of people with developmental and acquired disabilities. Alongside new medical and technical approaches to health, we have also developed a better grasp of the social determinants of well-being. In the case of an aging population, we have shifted away from discussions about death and dying, instead focusing on people's autonomy and choice, safety, and competence. Today, the vision of placing people with disabilities in isolated institutions appears to be insensitive and heartless. We value the principles of self-determination and community inclusion. As mentioned earlier, on the one hand, we strive to offer people with disabilities the best quality of life; on the other, we need to justify the financial resources necessary to support our commitment to the needs of the disabled [3, 4].

## Challenges of serving people with disabilities

Housing people with disabilities in large residential centers (institutions) today sounds inhumane. We are in an era focused on human rights, the rights of persons with disabilities, self-determination, and inclusion. People with disabilities often need the support from others in daily living activities. This need limits the ability to control their own lives, creating vulnerability and dependency toward the general population. People with disabilities receive support from family members, volunteers, and/or paid workers [4].

For centuries, people with disabilities were stigmatized, marginalized, and neglected [5]. With new theoretical approaches based on human rights and the importance of inclusivity, social relations, and interdependence [2, 6], we now examine the welfare of individuals with disabilities through questioning (Critical Disability Theory) former approaches to disabilities [6, 7]. Today, we see disabilities as a dynamic process that evolves with an individual's age and health status. Every person may one day become a person with a disability. There is no longer an "us" and "them". In accordance with Living Disability Theory, we work collaboratively with people with disabilities to improve their quality of life [8]. People with disabilities are highly diverse in terms of barriers to employment and access to society as a whole. These barriers include factors related to physical or cognitive abilities, stigma tied to sociocultural background, and the effects of social marginalization, such as low education level and poverty. We view disability through different dimensions of human existence, paying attention to education, housing, employment, and health care [2].

Unfortunately, although we have made significant progress in understanding the impact of disability on social policies, funding remains insufficient to make further progress. Government and public funding is limited, and frequently, available funds go unused because people are not aware of them [9]. In these circumstances, the cost of living of people with disabilities is too high to fully support many initiatives for independence and inclusivity.

There is no extensive research on the actual cost of living for people with disabilities and their caregivers. This is an important issue because even the best ideas for independent living in the community and promoting access to necessary services and activities might not be realistic due to financial constraints. We need a better understanding of how to implement the principles of "moral economy" when resources are insufficient [2].

In this article (Part I) and the accompanying article (Part II), we will concentrate on the living compound that provides services for people with disabilities in the places where they live, available whenever needed, day or night. We will focus on paid care providers who offer their services in healthcare provider agencies, group homes, intermediate care facilities (ICFs), or any other housing system intended for people with disabilities. Depending on the type of disability, this group of professionals faces significant challenges in supporting their clients.

To meet the demands of housing and supporting people with disabilities, the costs of assistance need to be reasonable, if not low. To reduce the cost, we need to consider the minimum possible requirements concerning the level of education and experience of paid workers assisting people with disabilities. However, this may lead to inadequate preparation of direct service staff in specialized housing for persons with disabilities. Poorly trained staff often leads to a well-known lack of competence and low confidence among professional staff such as nurses and social workers working in the field of developmental disability [10]. These conditions, in total, create substandard services for people with disabilities.

There are research data informing about the needs of people with disabilities concerning their housing condi-

tions. Following the process of de-institutionalization, we now consider two different models of housing: healthcare provider agency homes, commonly (if erroneously) synonymous with ICFs and/or group homes, and individualized housing with available specialized services. Each model has its limitations, but when considering financial management and economical constraints, healthcare provider homes seem to be the most practical. Research on quality of life has shown that each facility needs to feel like a "home", where residents feel safe and can treat the space as their own. They need to have the right to choose with whom they share their private space and the freedom to organize their time and environment. Given their vulnerability, the power imbalance between staff and residents in each housing setting needs to be considered and regularly evaluated [11, 12].

Another significant issue is the separation between community mental health organizations and the developmental disabilities system. Organizations that offer mental health services are often not well-equipped to assist people with developmental disabilities. In addition, disability services are not well integrated with the bio-psycho-social approach of social services [10].

**Lessons from an international approach: goals and research methods**

Across the world, people with disabilities present challenges to the economy of their families and the communities they live in. National governments and private health insurance companies attempt to establish a basic financial safety net to improve their living conditions and support their caregivers, most often their families. People with disabilities, due to their conditions, often have difficulties accessing available resources and making others aware of their problems. Their political impact is insufficient, and they are at constant risk of becoming a forgotten group of citizens.

Frąckiewicz [13] categorized different countries based on population income and how their level of a poverty (or wealth) affects their attitudes toward people with disabilities. She noted that, for example, Poland, the last country in the post-Soviet region to implement de-institutionalization of housing for people with disabilities, lacks sufficient options for independent housing. According to Frąckiewicz, people with disabilities have become just another "invisible group" in society, not quite free from institutions and unable to achieve the independence of having their own home and participating in community life [13].

The authors of this article examine the international approach to social work, especially in the context of "invisible groups", and we are acutely aware that this "invisibility" is often a function of available financial resources and political power. Unfortunately, people with disabilities lack political power, and their financial resources are very limited. In Poland, housing and specialized services for individuals with disabilities are scarce [14]. However, Poland does have a very good policy that outlines the rights of persons with disabilities. Unfortunately, instead of giving power to social activists, these legislative norms restrict people's freedom of choice and self-determination.

The system of care for individuals with disabilities struggles with insufficient public financial support. In her studies on people with old age and intellectual disability, Żabińska [1] concluded that there were two most important needs for people from the groups she studied: professional help services and housing appropriate to the nature of the individual's disabilities and limitations. According to Komorowska and Kozłowski [15], the most unmet need among people with cognitive disability is housing.

Communities often face the decision of whether to establish affordable housing facilities with limited services or to create different housing programs tailored to the needs and means of people with disabilities. The goal of our studies is to evaluate different approaches across countries in designing the best professional help and housing services for people with disabilities. While we understand that such solutions can be far from the model described by Critical Disability Theory, we are interested in understanding how the economy and financial constraints limit the achievement of such an ideal. We will discuss different organizations of public and private care systems for people with disabilities in Poland (Part I) and propose a model for system improvements based on research in public health and the increase in service costs in the US (Part II). Since Poland and the US have similar economic systems but different traditions of public services, it might be of value to assess how different approaches can help improve the care of people with disabilities.

The subject of this research is the management of the system of support, assistance, and care for people with disabilities, based on a review of the specific forms of care and support in Poland and the USA. The main method used in both parts of the article is secondary research on various aspects of management. The theoretical basis is provided by studies conducted by experts in the field of disability, mainly politicians, sociologists, economists, and demographers – indicating the need to change the current model of assistance and support.

The main purpose of the study is to present the state of knowledge regarding proposed solutions offered by the social assistance system. Our research takes the form of a scoping review of articles published in Polish and English, often focusing on authors' exploration of financial management of services for people with disabilities. We also evaluated the special needs and conditions related to diversity among disabilities and how this diversity affects social response. The fact that authors are professionals in each of the countries studied brings additional value to understanding the dynamics and history of social changes in the field of disability.

The value of the history of how different cultures and political systems address social work with vulnerable groups is especially informative when studying the situation in Ukraine, a country undergoing slow systemic change due to Russian domination [16, 17]. Comparing Ukraine to the rest of Europe also provides useful insights [18].

**Some features of the care and support system for people with disabilities in Poland**

When approaching the issue of management, or rather the allocation of financial resources for the care of people with disabilities, several key factors in the aid, support, and care system should be considered. The most crucial thing is the availability of care, medical, rehabilitation, and nursing services for all individuals, regardless of whether they have a legally recognized disability or subjectively feel that they are not fully functional. Building a system of broadly understood care for people with disabilities is a challenging task, as it requires meeting numerous conditions. It is undoubtedly important to precisely diagnose the barriers and obstacles to the social and spatial functioning of people with disabilities.

According to experts in the field of public policy for people with disabilities, there is a long list of problems to solve, which makes it difficult to construct an optimal system of care and support for this diverse social category. According to Agnieszka Dudzińska, "an accurate and comprehensive description of the specificity of various types of disabilities is not possible, because there are as many types of disabilities as there are people with various dysfunctions" [19]. Based on data from Statistics Poland, individuals with disabilities constitute quite a large population especially among the elderly, but also among middle-aged people. For example, among those aged 40–49, people with disabilities constitute 7.9%, but at the age of 50–59 the proportion is 15.1%, at the age of 60–69 the percentage increases and amounts to 22.9%, while at the age of 70–79 it is 32.5%, with the highest percentage falling in the age category of 80 years and over. More than half of people with disabilities are in this age group (52.2%) [20].

In Poland, the system of support, assistance, and care for people with disabilities is extensive, with many forms of support provided within the home environment. According to the Act on Social Assistance for Disabled Persons, forms of assistance include a fairly long catalog of allowances and benefits, care services, and placements in day and 24-hour care facilities. The availability of these forms of support depends on the individual's degree of disability, age, and financial situation. One example of support for older people and people with disabilities is care services, well-documented professional help offered to people who cannot manage their daily tasks on their own. Eligibility for such services is precisely defined and depends on financial and social support [21].

One of the goals of the article is to draw attention to a specific phenomenon in the field of organizing the protective role of the state towards people with disabilities. This phenomenon involves taking action aimed at deinstitutionalization in the field of 24-hour care and expansion of access to medical services, while, paradoxically, facilitating the process of the institutionalization of commercial services.

According to Zofia Szweda-Lewandowska, there are no comprehensive public statistics regarding the population of potential caregivers or the number of people requiring support. Information is also lacking on care provided within the family network and within the 'gray zone' of unregulated care services [22].

Based on the analyses carried out by Polish researchers, it appears that environmental support for individual groups varies significantly by group due to their diverse needs. Elderly individuals, people with disabilities, and other children and youth in foster require specific types of assistance [23]. People with multiple disabilities have specific needs, e.g. deaf-blind individuals, who require a different type of support from those with only impaired hearing or vision [24].

In the opinion of Paweł Kubicki, separating policies for people with disabilities and those for the elderly means that the expected changes in the field of deinstitutionalization and defamiliarization of assistance are unlikely to be realistic. The researcher sees the reason as the habits and expectations of older adults as well as the resistance among existing institutions and the limited influence of the community of people with disabilities [25]

Analyses by Polish researchers clearly show that there is a great demand for caregivers for the elderly, currently estimated at around 350,000, and it is expected that as many as 500,000 caregivers will be needed in 2035 [22].

Social welfare and private care homes in Poland are divided into the following types: 1) for chronically mentally ill individuals; 2) for the elderly; 3) for adults with intellectual disabilities; 4) for children and young people with intellectual disabilities; 5) for people with physical disabilities; and 6) for those addicted to alcohol. In Poland, most care for the elderly and disabled is provided by families. Despite the expansion of the private care services sector, institutional care, i.e. nursing homes, is usually considered a last resort rather than a choice. It is worth noting that there is also new research concerning the financial management of caregivers of children with disabilities [26].

If there was a diversified offer consisting in the availability of nursing homes with varying levels of rehabilitation and care services, there would probably be more interest in such solutions, depending on the needs of a disabled person. In practice, most social welfare homes in Poland combine care functions, offering assistance to disabled people and the elderly. The exception are homes for individuals with intellectual disabilities. There are also small, family-style community homes for people with intellectual disabilities, where they live alongside assistants. In Poland, they are run by the L'ARCHE foundation in Wrocław (since 2002). It manages two houses, each accommodating six to seven residents living together.

In Poland, there is a noticeable shortage of small nursing homes with a community-based character that replicate family-like conditions. The obstacles are high standards regarding equipment and the need to meet all the conditions contained in the regulations regarding facilities for people with disability. Financing such houses is a problem as well. For parents of adult children with disabilities, the greatest concern is care for their disabled child after their death. Associations, foundations, and church orga-

nizations are trying to solve this problem. Generally, parents of disabled children are reluctant to place their child in a social welfare home. In Poland, there are examples of communities specifically designed for people with intellectual disabilities which serve as alternatives to social welfare homes. These alternatives provide a safe and welcoming environment to live in conditions similar to a family home.

The optimal form of assistance for adults with disabilities is "supported housing", which provides living services and assistance in performing activities necessary for everyday functioning. The aim of this assistance is to maintain and develop the independence of a person with a disability based on the level of his or her psychophysical capabilities. The duration of stay in such apartments is not limited. A similar function is served by "training apartments", which are intended to provide living services, strengthen independence, and improve self-care skills. They are also designed to promote social integration and are intended specifically for people with intellectual disabilities. The duration of stay in training apartments is time-limited. As of 2021, there were 1,475 apartments in Poland (including supported and training apartments), housing 4,454 individuals. Using care options such as supported housing and training apartments is a very good alternative to living in an institution, i.e. in a social welfare home.

In Polish tradition, the choice of an institutional form, i.e. a social welfare home, has been and continues to be considered as a last resort. According to Statistics Poland (pl. Główny Urząd Statystyczny, GUS), as of December 31, 2022, there were 2,082 stationary care facilities operating with a total of 131.5 thousand places. However, only 118.8 thousand people stayed in these facilities (including 58.6 thousand women), which shows that there are vacancies, mainly in the private sector.

The costs of stay, regardless of whether they are nursing homes in the public or private sector, depend on the standard of the facility, its location, and the size of the town. For example, there are 14 social welfare homes in Warsaw, and the cost of stay typically exceeds PLN 9,000 per month. There are also four homes run by religious congregations, where the cost is slightly lower, from PLN 7,000 to 8,000. A nursing home for Alzheimer's patients charges PLN 9,000 for care. Private nursing homes in Warsaw have varying prices, often reaching several thousand PLN per month of stay. In 2023, the average monthly salary in Poland was PLN 7,590. Some private homes also accept individuals whose stay is financed by social welfare centers.

Some private nursing homes offer rehabilitation stays lasting 14 days, combined with an individual rehabilitation program. The range of physiotherapy treatments is very wide, including therapies based on special methods, classic massages, physical therapy, and kinesitherapy. However, not all private homes disclose the actual costs of stay, i.e. the cost of above-standard physiotherapy services. Private nursing homes theoretically offer a broader package of services and have professional equipment. The wider the package of services offered, the higher the cost of stay. For example, in Warsaw, the cost is PLN 8,000, while in the Kuyavian-Pomeranian Voivodeship it is PLN 5,500. Some nursing homes offer a one-day stay for PLN 210 or PLN 300, with a package of therapeutic services already included. It is also worth adding that disabled individuals living in social welfare homes in the public sector can apply for funding for participation in rehabilitation stays if they meet the conditions set out in the law regarding the rehabilitation of disabled people.

The costs of stay in private homes are typically quite high, reflecting the living conditions in Poland, and are typically higher than the costs of staying in the public sector. Based on the offers from private homes, prices for a multi-person room start from PLN 5,000 per month (with rehabilitation treatments included) to PLN 8,600 for a single room (excluding medicines and hygiene products). Most private nursing homes offer a range of services including nursing care, medical care, support of care staff, rehabilitation treatments, and occupational therapy. Longer stays are preferred, and if the services are used for only one month, the cost is higher. There is no detailed information on the frequency of physiotherapy services; generally, it is stated as being "dependent on the condition and recommendations of the physiotherapist". Some private nursing homes offer luxury facilities with a full range of rehabilitation services and advertise their modern rehabilitation equipment. Prices for a monthly stay are higher than standard rates, e.g. a stay in a single room can cost PLN 7,000. The advantage of these homes is their location outside the city, near forests, parks, and recreational areas. In addition to private nursing homes, disabled people (regardless of age) can use a wide range of services at private rehabilitation centers that offer physiotherapy, rehabilitation and correction services, electrotherapy, laser therapy, kinesiotherapy, massage treatments, etc. In such outpatient centers, prices vary between PLN 160 and PLN 180 for an individual 50-minute therapeutic treatment.

**Creating a home and offering rehabilitation services for people with disabilities**

There is currently an ongoing discussion in Poland on how to effectively help people with disabilities. The concept of comprehensive rehabilitation aimed at recovery and return to work is sound but difficult to implement. In other countries, investments are made in physiotherapy to reduce treatment costs and ensure that patients have fewer complications, stay in hospital for a shorter time, and do not require third-party care. Rehabilitation can take place in hospitals, outpatient clinics, and home settings. Financial resources allocated for rehabilitation treatments vary, which affects the availability of physiotherapy services. The crisis in Polish physiotherapy is largely due to low remuneration rates for physiotherapists set by the National Health Fund (pl. Narodowy Fundusz Zdrowia, NFZ). The effects are most acutely felt by people who need home rehabilitation, as the rates for these services are the lowest. Accessing rehabilitation services through the NFZ is challenging.

Rehabilitation services for people with disabilities are available as a part of rehabilitation stays, which are organized and co-financed by the State Fund for the Rehabilitation of Disabled Persons (pl. Państwowy Fundusz Rehabilitacji Osób Niepełnosprawnych, PFRON). This form of service is intended for individuals who have a certificate of significant or moderate disability, or a certificate

of total or partial incapacity for work. It is also available to people with disabilities who are under 16 years old and those who are under 24 years old but still studying, generally for individuals who are not employed. The stay at these camps is aimed at therapeutic and social rehabilitation, with participants engaging in group activities and learning to become more independent.

One of the goals in planning services for people with disabilities is the creation of rehabilitation services that would allow them to improve their financial situation. Such services could diminish physical barriers in accessing the workplace and vocational education, especially when learning new technologies [18]. However, the most common need remains improving physical accessibility to gain as much independence as possible.

It is worth noting that there are 75,000 physiotherapists working in Poland, but only 29,000 are under contracts with the NFZ. According to official data, only 38% of patients can benefit from free care in this area. The problem lies in the unavailability of physiotherapy, resulting in excessively long waiting times for rehabilitation treatments. Most Poles rely on the services of private physiotherapy offices, mostly out of necessity rather than choice. In Poland, there are 1,005 facilities providing free advice as part of orthopedic services offered by the NFZ. The average waiting time for an appointment with an orthopedist is 110 days, but in the voivodeships with the longest waitlists it can extend to as much as 151 days (as of August 27, 2023). Therefore, for those needing prompt advice from an orthopedist, the only option is to seek private consultations, which can be arranged within a few days or even immediately. The cost of one visit, depending on the town and facility, is PLN 200–300. Other free medical services covered by the NFZ also require long waiting times; for example, the average waiting time for a free cardiologist appointment is 5.7 months, for a pediatric cardiologist 7.3 months, for a consultation with a neurosurgeon 5.3 months, and with an immunologist 9 months.

A key issue in the discussion about disability problems is the availability of rehabilitation services and the costs associated with providing them. In Poland, four entities are responsible for the financing of therapeutic rehabilitation: 1) the NFZ; 2) the Social Insurance Institution (pl. Zakład Ubezpieczeń Społecznych, ZUS); 3) the Agricultural Social Insurance Fund (pl. Kasa Rolniczego Ubezpieczenia Społecznego, KRUS); and 4) the Provincial Occupational Medicine Center (pl. Wojewódzki Ośrodek Medycyny Pracy, WOMP). In 2020, another source of financing was introduced, with the commencement of benefits for people with disabilities from the Solidarity Fund. The most important entity is the NFZ, which spends approximately ninety percent of public funds allocated to therapeutic rehabilitation.

According to the Supreme Audit Office report [27], the Polish system lacks coordination of treatment within the public health care system. In 2019, 3.5 million people benefited from therapeutic rehabilitation, but not all patients did so at the most appropriate time for rehabilitation. Institutions financing rehabilitation do not create a coherent system. Therapeutic rehabilitation should be a mandatory treatment profile within the system of basic hospital health care services [27].

**Plan for the future. Practical and theoretical conclusions**

On the one hand, the principle of deinstitutionalization is implemented in official policy, while on the other, the phenomenon of institutionalization occurs. This is evident in the private care sector, where there is an increase in the number of private institutions providing commercial care services, and in the rise in the number of nursing homes intended for both older people with disabilities and younger individuals with physical limitations.

The best conclusion for this study is the annual action plan for people with disabilities announced by the Ministry of Family and Social Policy. It will continue tasks related to the implementation of the respite policy for caregivers of disabled people, activities in the field of personal assistance for people with disabilities, as well as initiatives under the "Centers" program for care and housing. The aim of this program is to assist adults with disabilities and to provide accommodation, care, and specialized services tailored to their needs. In general, housing for people with disabilities is more expensive when additional services are offered. People with disabilities and their families can choose the standard of housing (and their price) with specialized assistance or opt for less expensive housing and seek external services that are not easy to access. The goal of the action plan is to improve access to rehabilitation services. The solution of more addordable housing and external professional services seems to be the most realistic for people and families with limited incomes and higher costs of living [28]. The presented plan is the closest to the ideal described by Critical Disability Theory, though it still requires greater social awareness that the quality of life of people with disabilities is important for all members of the society [29, 30].

The ministerial plan for 2024 also includes the implementation of the "Family Support Centers" program, which involves creating a support system in various areas of life for people with disabilities and their families. The program is set to be implemented by entities and units that are not part of the public finance sector. While these are important, they are complementary activities. A health policy ensuring coherent actions across the entire health care and rehabilitation system for people with disabilities would be much more important. The experience of recent years has proven that it is necessary to repair the entire system and synchronize therapeutic and rehabilitation efforts.

It should be added that an important new form of support for people with disabilities, called Supported Living Communities, is set to be launched in 2025. Access to this form of assistance will be determined by provincial teams for assessing disability – based on a scale from 70 to 100 points measuring the need for support. Recruitment to the Supported Housing Communities will be carried out by organizations without the involvement of PFRON, while the stay, scope, and type of services will be regulated by the provisions of the contracts concluded between residents and the organization running the facility. It is planned that the financing of this form of support will be provided by PFRON, with a fifty percent contribution from the residents themselves. It is hoped that people with disabilities in this form of housing will be able to receive care in accordance with their individual needs resulting from limited

mobility. The future will show what the long-term effects and costs of running such facilities will be.

One of the most interesting responses from Polish people with disabilities and their families is their organization into a voluntary movement and support system. They have established voluntary groups and communities that help their members share information and resources, which can also fuel political advocacy [13].

The systematic approach to solving the financial conundrum of improving quality of life with limited financial resources is suggested by the H.O.P.E Network, an organization based in Cleveland, Ohio, and presented in Part II of this work.

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# LAPAROSCOPIC APPENDECTOMY AS AN ALTERNATIVE TO OPEN APPENDECTOMY – A SINGLE-CENTER EXPERIENCE

## Appendektomia laparoskopowa jako alternatywa dla metody klasycznej – doświadczenia własne

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**Abstract**

**Introduction and objective:** Acute appendicitis is one of the most common acute emergencies in general surgery. Laparoscopic procedures in acute abdominal diseases require particular skills and experience from the surgeon, because the anatomical conditions and the image of the abdominal cavity are usually altered, with swollen and brittle tissues, by ongoing acute inflammation. Appendectomy can be performed using both open and laparoscopic methods. In the era of minimally invasive procedures, appendectomy is most often performed using the latter approach. The aim of the study was to assess the impact of the type of surgical approach (open or laparoscopic appendectomy) on the length of hospital stay, patients' recovery and postoperative complications. **Materials and methods:** The analysis included patients operated on in the Department of Thoracic, General and Oncological Surgery between 2020 and 2023 due to acute appendicitis. The patients underwent emergency surgery using open or laparoscopic methods. All patients were qualified for a follow-up appointment at the hospital surgical clinic (appointments took place on day 10 after the primary surgery or relaparotomy). **Results:** The study group was divided based on age, gender and the type of surgical procedure performed (open versus laparoscopic). The severity of pain on days 1 and 10 postoperatively, the occurrence of postoperative complications, and the duration of hospital stay were also assessed. **Conclusions:** It was concluded based on the results obtained that compared to open appendectomy, laparoscopic procedure was associated with lower rates of postoperative complications, reduced pain and shorter hospital stay.

**Streszczenie**

**Wprowadzenie i cel:** Ostre zapalenie wyrostka robaczkowego jest jednym z najczęstszych ostrych stanów w chirurgii ogólnej. Laparoskopowe zabiegi w ostrych schorzeniach jamy brzusznej wymagają szczególnych umiejętności i doświadczenia operatora, ponieważ zwykle warunki anatomiczne oraz obraz jamy brzusznej są zmienione przez toczący się ostry stan zapalny, a tkanki są obrzęknięte i kruche. Appendektomię możemy wykonać metodą klasyczną lub laparoskopową. W dobie przewagi zabiegów małoinwazyjnych również usunięcie wyrostka robaczkowego najczęściej wykonuje się tą metodą. Celem pracy była ocena wpływu rodzaju zabiegu (appendektomii klasycznej lub laparoskopowej) na czas hospitalizacji, okres rekonwalescencji i występowanie powikłań pooperacyjnych. **Materiał i metody:** Analizie poddano pacjentów operowanych w Klinice Chirurgii Klatki Piersiowej, Chirurgii Ogólnej i Onkologicznej w latach 2020–2023 z powodu ostrego zapalenia wyrostka robaczkowego. Badani byli operowania w trybie ostrym i wykonywano u nich appendektomię klasyczną lub laparoskopową. Wszystkich badanych zakwalifikowano do kontroli w przyszpitalnej poradni chirurgicznej (wizyty odbywały się w 10. dobie od pierwotnego zabiegu operacyjnego lub relaparotomii). **Wyniki:** W badanej grupie, którą podzielono ze względu na wiek, płeć i rodzaj wykonanego zabiegu operacyjnego (klasyczny, laparoskopowy), oceniano nasilenie dolegliwości bólowych w pierwszej i 10. dobie po zabiegu operacyjnym, występowanie powikłań pooperacyjnych oraz czas hospitalizacji. **Wnioski:** Na podstawie uzyskanych wyników wysunięto wniosek, że appendektomia laparoskopowa w porównaniu z klasyczną jest metodą pozwalającą na ograniczenie liczby powikłań pooperacyjnych, zmniejszenie dolegliwościach bólowych u pacjentów oraz skrócenie czasu hospitalizacji.

**Keywords:** laparoscopic appendectomy; postoperative complications; pain; acute appendicitis; open appendectomy

**Słowa kluczowe:** appendektomia laparoskopowa; powikłania pooperacyjne; dolegliwości bólowe; ostre zapalenie wyrostka robaczkowego; appendektomia klasyczna

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## Introduction

Acute appendicitis (AA) is one of the most common acute emergencies in general surgery. The incidence of AA ranges from 76 to 227 per 100,000 population per year in developed countries. Appendectomies account for about 5% of all interventions in general surgical settings [1–3]. The vast majority of patients are children and young adults, predominantly males. Women >40 years of age are significantly more likely to develop AA. Acute appendicitis is very rare in children under 5 years of age, neonates in particular. This is most likely due to their wide appendix, reducing the risk of its proximal obstruction. AA is more common in European countries than in Africa and Asia. This is probably related to a diet high in carbohydrates and low in fibre, as well as genetic factors [1–4].

Appendectomy is performed using either the open or laparoscopic approach. In the era of minimally invasive procedures, the latter method is more popular. The first fully laparoscopic appendectomy was performed in 1980 by gynaecologist Kurt Semm [2, 5, 6]. However, this technique did not gain wide acceptance for many years. It had its heyday at the beginning of the 21st century, when surgeons began to acquire technical skills essential for performing this type of procedure. Laparoscopic procedures are gaining wider application not only in elective surgery, but also in the diagnosis and treatment of acute abdominal conditions. They require particular skills and experience from surgeons, as the anatomical conditions and the image of the abdominal cavity are usually altered, with swollen and brittle tissues, by ongoing acute inflammation. Nevertheless, encouraged by the benefits of minimally invasive methods, surgeons are increasingly more likely to choose these approaches also for appendectomy [2, 5–9].

## Objective

The aim of the study was to assess the impact of surgical approach (open vs. laparoscopic appendectomy) on the length of hospital stay, recovery and postoperative complications. Other non-modifiable factors (age, gender) were also considered.

## Materials and methods

Patients operated on at the Department of Thoracic, General and Oncological Surgery in the years 2020–2023 due to acute appendicitis were included in the analysis. The patients underwent emergency surgery using either open or laparoscopic approach.

The open procedure was performed with an oblique, about 5 cm incision at McBurney's point. The entire abdominal cavity was inspected for pathology. The mesentery of the appendix was divided and single ligatures were placed. The appendix was ligated at the base and removed. A purse-string suture was placed on the caecum, followed by a securing z-suture. A small bowel segment of about 50 cm was inspected for Meckel's diverticulum. A layer-by-layer reconstruction of the integuments was performed, and single stitches were placed on the subcutaneous tissue and skin.

Laparoscopic procedures started with direct umbilical trocar insertion and creation of a pneumoperitoneum of up to 12 mm Hg. This was followed by insertion of the remaining trocars in the lower abdomen, slightly to the left, and in the right mid-abdomen. The entire abdominal cavity was inspected for pathology. After locating the appendix, the mesentery of the appendix was divided and removed after clipping. Then the appendix was dissected, secured with Hem-o-lock clips and removed. The peritoneal cavity was rinsed with physiological saline solution and classical layer-by-layer suturing of the integuments was performed.

All patients were qualified for a follow-up at the hospital surgical clinic (visits took place on day 10 after the primary procedure or relaparotomy). The study group consisted of patients who underwent a follow-up at the hospital's general surgery clinic after appendectomy. A total of 328 patients (176 women and 152 men) reported for their visit. All patients received perioperative infection prophylaxis (cephalosporin at a single preoperative dose of 1.0 g).

Available medical records from the patients' hospital stay and from the hospital general surgery clinic were retrospectively assessed.

The severity of pain was assessed using a visual analogue scale (VAS) on days 1 and 10 postoperatively. Patients used a dedicated ruler-like tool to rate their pain, where a score of 0 meant 'no pain', and 10 meant 'the worst pain imaginable'.

Statistical analysis was performed using Statistica 13. The Shapiro–Wilk test, Student's T-test, Friedman's ANOVA, and Kruskal-Wallis tests were used for calculations. A $p$-value <0.05 was considered statistically significant across all analyses.

## Results

The study group was assessed for the severity of pain on postoperative days 1 and 10, postoperative complications and length of hospital stay depending on age, gender and type of procedure performed (open vs. laparo-

scopic appendectomy). Early treatment outcomes (up to 10 days postoperatively) were evaluated. We did not assess the length of patients' incapacity for work, but only their subjective rating of pain.

**Characteristics of the study group – gender, age and surgical approach**

The study group included 176 women (54%) and 152 men (46%). The mean age was 44 years, with 70 patients aged ≥60 years (21%).

The mean age of patients undergoing laparoscopic and open surgery was 36 and 58 years, respectively.

The open approach was used in 92 patients (28%; women: 51%, men: 49%), and the laparoscopic method was used in 236 patients (72%; women: 52%, men: 48%). Among those ≥60 years old, the majority (63%) were treated with the open technique, whereas the laparoscopic approach was more common (81%) in the group of patients under 60 years of age. Patients in the laparoscopic group were statistically significantly younger ($p$ = 0.001479). No statistically significant relationship was found between gender and surgical approach ($p$ = 0.83174). The relationship between the age of patients and surgical technique used is shown in figure 1.

**Characteristics of the study group – postoperative complications**

There were no cases of mortality in the study group. Postoperative complications occurred in 21 patients (6.4%), including 4.6% in the laparoscopic group and 11% in the open approach group.

Impaired postoperative wound healing was found in 11 patients (3.4%), a wound haematoma requiring drainage was observed in 2 patients (0.6%), and reoperation due to interloop abscesses was needed in 8 patients (2.4%). Statistically significantly lower rates of complications were found in the laparoscopic group ($p$ = 0.002179). No statistically significant differences were observed for the type of complications depending on surgical approach ($p$ = 0.76714). The relationship between postoperative complications and surgical technique is presented in figure 2.

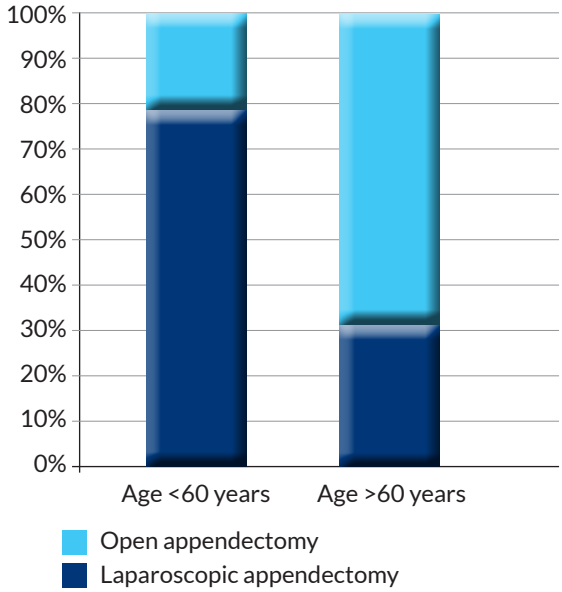


**Figure 1.** The relationship between age and surgical approach

**Characteristics of the study group – pain**

Pain was assessed both during hospital stay and at follow-up visits in the hospital's general surgery clinic.

The laparoscopic group rated their pain on postoperative day 1 as mild (VAS 1–3) ($n$ = 101, 43%) or moderate (VAS 4–6) ($n$ = 135, 57%). None of the patients reported severe pain (VAS >7). At 10 days postoperatively, 90 patients (38%) reported no pain, 145 patients reported mild pain (61%), and one person reported moderate pain (1%).

The open approach group rated their pain on postoperative day 1 as mild (VAS 1–3) ($n$ = 11, 11%), moderate (VAS 4–6) ($n$ = 80, 87%), and severe (VAS >7) ($n$ = 1, 2%). At 10 days postoperatively, 11 patients (12%) reported no pain, 78 patients reported mild pain (84%) and three patients experienced moderate pain (4%). A statistically significantly higher proportion of laparoscopically treated patients experienced no pain or their pain resolved on day 10 postoperatively ($p$ = 0.00038).

The severity of pain was significantly higher on the first postoperative day in the open approach group ($p$ = 0.00245). The relationship between surgical technique and the severity of pain on postoperative days 1 and 10 is presented in table 1.

**Characteristics of the study group – length of hospital stay**

The average length of hospital stay in the study group was 2.5 days (an average of 3.5 days in the open approach group and 2 days in the laparoscopic group). The average length of hospital stay was 4 and 2 days among patients ≥60 years and <60 years of age.

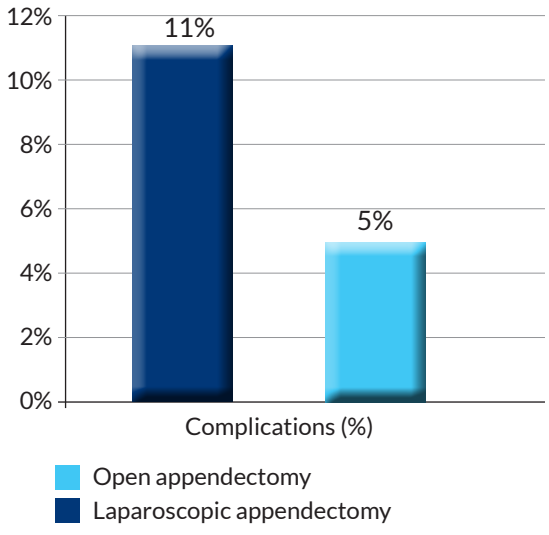


**Figure 2.** The relationship between postoperative complications and surgical approach

Statistical analysis showed a statistically significantly shorter hospitalisation among patients <60 years of age ($p$ = 0.000147).

A statistically significant difference in the length of hospital stay was also observed depending on surgical approach ($p$ = 0.00387). The relationship between length of hospitalisation and surgical approach is shown in figure 3.

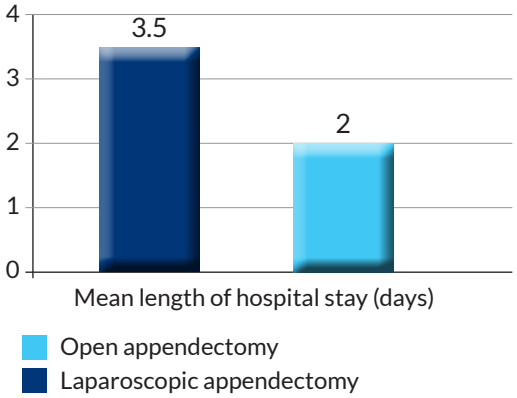


**Figure 3.** The relationship between the length of hospital stay and surgical approach

## Discussion

Acute appendicitis affects about 7% of the population. It is most often managed in the emergency surgical setting [3, 10]. Laparoscopic approach is the preferred option in these patients. This is due to the multiple benefits of minimally invasive surgery compared to open techniques. We assessed whether there is a relationship between the surgical method used (open vs. laparoscopic appendectomy) and the length of hospital stay, postoperative complications and the severity of postoperative pain.

The study showed that the majority of patients ≥60 years of age underwent an open procedure, whereas the laparoscopic approach was a more common option in the younger group. This is mostly due to the fact that older patients are likely to present with atypical symptoms, which may be associated with delayed diagnosis and disease progression. Almost half of the patients were under 40 years of age (49.4%), with only 15% of patients aged ≥65 years. Similar conclusions have been reported in the literature. As pointed out by Coher-Arazi, multimorbidity and polypharmacy may lead to a delayed diagnosis in older patients, which is associated with atypical presentation of clinical symptoms of AA [2]. Strzałka [9] also reached similar conclusions, indicating a statistically significantly lower age of laparoscopically treated patients. He also noted that women were more likely to undergo minimally invasive surgery.

We found no statistically significant relationship between gender and surgical approach ($p$ = 0.83174).

There were no cases of mortality in the study group. Postoperative complications occurred in 21 patients (6.4%) and included impaired healing of the postoperative wound, wound haematoma requiring drainage and interloop abscesses requiring reoperation.

Statistical analysis showed statistically significantly lower rates of complications in the laparoscopic group, with no relationship between the type of complication and surgical approach.

Lower rates of postoperative complications after laparoscopic appendectomy compared to open surgery have also been described in the literature. Additionally, some authors indicate an increased rate of intra-abdominal abscesses after laparoscopic surgery [11–14]. However, no such statistically significant correlations were observed in our study.

The length of hospital stay was another aspect taken into account in our research. Statistical analysis showed a significantly shorter hospital stay in both patients under 60 years of age and those who underwent laparoscopic appendectomy.

Other authors have also reported that longer hospital stay in patients over 60 years of age is related to their general health, comorbidities and impaired healing of postoperative wounds. Some authors have noted a correlation between the age of patients and the rate of complications, and thus the length of hospital stay [5, 7, 15–17]. No such statistically significant differences were observed in our study.

We used the VAS scale for pain measurement. Patients were asked to rate the intensity of pain on postoperative days 1 and 10. A significantly higher severity of postoperative pain was observed on the first day after open appendectomy. By contrast, there was a statistically significantly higher percentage of laparoscopically-treated patients reporting no pain or whose pain decreased on day 10 postoperatively.

Other authors have also emphasised less pain after laparoscopic appendectomy and a faster return to daily activity and work. Considering the costs of prolonged employee absence and the potential costs of rehabilitation or the use of analgesics, this seems invaluable [4–6, 10, 13].

## Conclusions

The following conclusion was drawn based on the obtained results: compared to open appendectomy, lapa-

**Table 1.** The relationship between age and surgical approach

| | Pain on day 1 | | | | Pain on day 10 | | | |
|---|---|---|---|---|---|---|---|---|
| | No | Mild | Moderate | Severe | No | Mild | Moderate | Severe |
| **Open appendectomy** | 0 | 11 | 80 | 1 | 11 | 78 | 3 | 0 |
| **Laparoscopic appendectomy** | 0 | 101 | 135 | 0 | 90 | 145 | 1 | 0 |

roscopy decreases the rates of postoperative complications, as well as is associated with less pain and a shorter hospital stay.

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# EFFECTS OF SHOCK WAVE THERAPY ON ERECTILE DYSFUNCTION – A PILOT STUDY

## Ocena efektów leczenia terapii zaburzeń erekcji metodą fali uderzeniowej – badanie pilotażowe

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### Abstract

**Introduction and objective:** Erectile dysfunction has become an increasingly common issue and is predictive of various cardiovascular and mental conditions. This study focuses on low-intensity extracorporeal shock wave therapy (Li-ESWT), which is recognised by the European Association of Urology as an adjunct to first-line treatment for erectile function. Li-ESWT can be an alternative to or complement pharmacotherapy (phosphodiesterase type 5 inhibitors). It is painless, non-invasive, and safe for the patient, as confirmed by numerous studies. **Material and methods:** The study included a group of 40 men receiving Li-ESWT treatment once a week. Treatment parameters were established based on the Motil algorithm following a qualifying appointment and exclusion of contraindications. Patients were assessed three times: before, immediately after, and six months post-treatment, using the International Index of Erectile Function-5 Questionnaire (IIEF-5). **Results:** The pre-treatment IIEF-5 score in the study group was 12.6 ± 3.9 increased to an average of 18.0 ± 3.4 points after treatment. Six months post-treatment, a further increase was noted to an average score of 18.9 ± 4.1 – statistically significant differences ($p$ <0.05). A negative correlation was observed between the duration of erectile dysfunction and the results before treatment (−0.3526; $p$ <0.05 – average correlation), immediately after (−0.0777; $p$ <0.05 – low correlation), and six months after (−0.5180; $p$ <0.05 – high correlation) the end of treatment. A positive correlation was observed between pre-treatment IIEF-5 scores and results immediately after treatment (0.6113; $p$ <0.05 – high correlation) and six months (0.5207; $p$ < 0.05 – high correlation) after the end of treatment ($p$ <0.05). A negative correlation was observed between the number of shock wave pulses and IIEF-5 scores obtained before (−0.6963; $p$ <0.05 – high correlation), immediately after (−0.5885, $p$ <0.05 – high correlation), and six months after the end of treatment (−0.6884, $p$ <0.05 – high correlation). **Conclusions:** 1. Low-intense extracorporeal shock wave therapy improves erectile function in patients with erectile dysfunction. 2. Positive effects on erectile function, as assessed by IIEF-5, were observed immediately after treatment and persisted at six-month follow-up. 3. Erectile dysfunction duration negatively affected IIEF-5 scores before, immediately after, and six months post-treatment. 4. Patient age had no impact on IIEF-5 scores at the end of the treatment and at six-month follow-up.

### Streszczenie

**Wprowadzenie i cel:** Zaburzenia erekcji stają się coraz powszechniejszym problemem i są predyktorem różnych schorzeń sercowo-naczyniowych i psychicznych. Niniejsze badanie koncentruje się na terapii pozaustrojową falą uderzeniową o niskiej intensywności (Li-ESWT), która jest uznawana przez Europejskie Towarzystwo Urologiczne za leczenie pierwszego rzutu zaburzeń funkcji erekcyjnej. Li-ESWT może być alternatywą lub uzupełnieniem farmakoterapii (inhibitory fosfodiesterazy typu 5). Metoda ta jest bezbolesna, nieinwazyjna i bezpieczna dla pacjenta, co potwierdzają liczne badania. **Materiał i metody:** Badanie objęło grupę 40 mężczyzn otrzymujących leczenie Li-ESWT raz w tygodniu. Parametry terapii ustalono na podstawie algorytmu Motila po wizycie kwalifikacyjnej i wykluczeniu przeciwwskazań. Pacjenci byli oceniani trzykrotnie: przed, bezpośrednio po i sześć miesięcy po leczeniu, przy użyciu Międzynarodowego Kwestionariusza Funkcji Erekcji-5 (IIEF-5). **Wyniki:** Wynik IIEF-5 przed leczeniem w grupie badanej wynosił 12,6 ± 3,9 i wzrósł do średnio 18,0 ± 3,4 punktów po leczeniu. Sześć miesięcy po leczeniu odnotowano dalszy wzrost do średniego wyniku 18,9 ± 4,1 – różnice statystycznie istotne ($p$ <0,05). Zaobserwowano ujemną korelację między czasem trwania zaburzeń erekcji a wynikami przed leczeniem (−0,3526; $p$ <0,05 – średnia korelacja), bezpośrednio po (−0,0777; $p$ <0,05 – niska korelacja) i sześć miesięcy po (−0,5180; $p$ <0,05 – wysoka korelacja) zakończeniu leczenia. Zaobserwowano dodatnią korelację między wynikami IIEF-5 przed leczeniem a wynikami bezpośrednio po leczeniu (0,6113; $p$ <0,05 – wysoka korelacja) i sześć miesięcy (0,5207; $p$ <0,05 – wysoka korelacja) po zakończeniu leczenia ($p$ <0,05). Zaobserwowano ujemną korelację między liczbą impulsów fali uderzeniowej a wynikami IIEF-5 uzyskanymi przed (−0,6963; $p$ <0,05 – wysoka korelacja), bezpośrednio po (−0,5885, $p$ <0,05 – wysoka korelacja) i sześć miesięcy po zakończeniu leczenia (−0,6884, $p$ <0,05 – wysoka korelacja). **Wnioski:** 1. Terapia falą uderzeniową pozaustrojową o niskiej intensywności poprawia funk-

cje erekcji u pacjentów z zaburzeniami erekcji. 2. Pozytywne efekty dotyczące funkcji erekcji, oceniane według skali IIEF-5, obserwowano bezpośrednio po leczeniu i utrzymywały się podczas sześciomiesięcznej obserwacji. 3. Czas trwania zaburzeń erekcji negatywnie wpływał na wyniki skali IIEF-5 przed leczeniem, bezpośrednio po nim i sześć miesięcy po leczeniu. 4. Wiek pacjenta nie miał wpływu na wyniki skali IIEF-5 pod koniec leczenia i podczas sześciomiesięcznej obserwacji.

**Keywords:** angiogenesis; erectile dysfunction; vascular erectile dysfunction; low-intensity shock wave therapy

**Słowa kluczowe:** angiogeneza; zaburzenia erekcji; naczyniopochodne zaburzenia erekcji; niskoczęstotliwościowa fala uderzeniowa

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**Epidemiology of erectile dysfunction**

It is estimated that approximately 50% of men worldwide suffer from erectile dysfunction (ED), based on a study involving nearly 100,000 individuals aged 40–70 years from Brazil, China, France, Germany, Italy, Spain, the United Kingdom and the United States [1], and the issue is affecting increasingly younger men [2]. In Poland, 25–30% of men aged 30–50 years (approximately 3 million), experience problems with erectile function (EF) [3]. The risk factors for ED include hypertension, diabetes mellitus, and hypercholesterolaemia, which may have a direct effect on penile haemodynamics by generating changes in the vascular network. Furthermore, ED is now also recognised as a predictor of adverse cardiovascular events [4]. In the pathogenesis of ED, hormonal secretion is significant, in particular the hypothalamic-pituitary axis [5], which affects testosterone production in the testes [6]. Prostate-specific antigen (PSA) is another important indicator in the assessment of cancer-related ED [7]. Other risk factors comprise obesity and poor nutrition, as increased body fat promotes the formation of oestrogens, impairing metabolism and altering body composition [8]. These changes are associated with a decrease in daily physical activity, the lack or insufficient level of which promotes the development of endocrine, metabolic, and cardiovascular diseases [9]. Moreover, psychogenic factors, such as depression or prolonged chronic stress, may play a substantial role in the onset of sexual dysfunction in men [10].

**Erectile dysfunction treatment modalities in men**

According to the latest guidelines and international standards, the treatment of ED is a multidisciplinary issue. It involves not only an urologist and an andrologist, but also a broader team of healthcare professionals, consisting of a psychotherapist, an endocrinologist, a general practitioner and, if necessary, specialists from other medical disciplines.

The 2021 European Association of Urology guidelines for the treatment of ED outline first-line treatment methods, which include phosphodiesterase type 5 inhibitors (PDE5i), vacuum erection devices (VEDs) and, in cases of vascular ED, low-intensity extracorporeal shock wave therapy (Li-ESWT), provided that patients have received proper pre-treatment counselling. In the absence of a positive response, second-line treatments, which include intracavernosal injections of vasoactive substances and combination therapy, are considered. Third-line treatment is based on penile implantation [11].

Early research into the use of Li-ESWT in ED dates back to the study by Gruenwald et al. [12] published a decade ago, which numerous subsequent authors have followed up on [13–17]. However, it was the pioneering work by Nishida et al. [18], Wang et al. [19], and Gotte et al. [20] on vascular angiogenesis and the mechanisms behind this process that initiated the entire debate. The effectiveness of Li-ESWT in the treatment of ED is most commonly assessed using subjective international questionnaires addressing issues with EF as well as self-perception. To objectify the results, methods such as ultrasound and plethysmography are used. Nevertheless, current research no longer focuses exclusively on assessing the applicability of Li-ESWT in the treatment of EF disorders in men, but rather on optimising the effects through the selection of appropriate parameters, type of equipment, and methodology of the procedure [21].

Furthermore, the assessment of long-term effects of Li-ESWT for ED is becoming a growing area of focus, as reflected in international guidelines and recommendations for further research in the field [11, 22]. Recent reports have suggested that attempts should be undertaken to extend the application of Li-ESWT for the treatment of EF disorders of non-vascular aetiology [23] and other uroandrological conditions [24].

The aim of the present study was to evaluate the effectiveness of Li-ESWT in the treatment of patients with ED, aged 30–80 years, in the Polish population, at a six-month follow-up.

**The underlying mechanism of Li-ESWT**

Li-ESWT is a mechanical wave characterised by high amplitude, lack of periodicity, pressure spikes, and low power and frequency, which is crucial for the treatment of patients with EF[25]. Numerous devices are used in clinical practice: electrohydraulic, electromagnetic or piezoelectric, converting electrical energy into mechani-

cal wave energy. Shock waves can be further subdivided according to the mode of propagation within the medium into focused shock wave therapy, radially propagating shock wave therapy, as well as planar shock wave therapy, which is less frequently used in ED patients [26].

Nevertheless, as emphasised at the 20th Congress of the European Society for Sexual Medicine and the 21st World Congress of the International Society for Sexual Medicine in 2018, there are no recommendations or guidelines in the available literature in terms of the apparatus models used to treat ED patients [22].

Porst et al. [21], in their study on the efficacy of Li-ESWT in the treatment of ED, analysed six types of Li-ESWT devices, which varied significantly in power density (0.09–0.55 mJ/mm$^2$). The team observed positive therapeutic effects with all the devices analysed, whether they generated the shock waves from electrohydraulic, electromagnetic, or piezoelectric sources. Interestingly, the study found significant differences with regard to the methodology of the treatment protocols. The authors suggested that higher energy levels might yield better therapeutic effects, although they require greater precision and focus in the area of the treatment protocol.

The underlying mechanism of Li-ESWT is the stimulation of the vascular endothelium and the activation of factors which promote blood vessel formation. One of the first studies addressing this topic was conducted by Nishida et al. [18], who observed that Li-ESWT application resulted in significant mRNA hyperexpression of potent angiogenesis ligands and protein expression in human umbilical vein endothelial cells (*in vitro*). They also reported a considerable improvement in regional myocardial blood flow (nine application sites, 200 impulses each; power density 0.09 mJ/mm$^2$, porcine studies – *in vivo*). Two possible mechanisms were identified: 1) enzymatic, which involves an increase in endothelial nitric oxide synthase activity [19], and 2) non-enzymatic, requiring the participation of L-arginine and hydrogen peroxide molecules [20]. Despite the obvious clinical effects of Li-ESWT, the exact mechanism by which it acts on tissues remains unknown. Li-ESWT exerts analgesic and anti-inflammatory effects, and it positively impact tissue remodelling by improving local blood circulation, thereby diminishing pathological processes directly associated with ischaemia of the corpora cavernosa. Furthermore, Li-ESWT is hypothesised to affect the cytoskeleton of the cell and, through a mechanotransduction mechanism, exert an effect on tissue metabolism [27]. Notably, immediately following Li-ESWT application, a reduction in the synthesis of pro-inflammatory cytokines, such as Il-1 beta, Il-6 and TNF-alpha is recorded [28], which may cause a transient decrease in temperature within the treatment site via a mechanism of primary vasoconstriction.

## Study group

The study involved 40 men with a mean age of 54.5 years (35–78 years ± 9.1 years), presenting with ED of an average duration of 2.9 years (0.5–12 years ± 2.5 years) (tab. 1). Exclusion criteria comprised laboratory results outside the reference range (LH, FSH, PSA, oestradiol, prolactin, testosterone), prostate and/or penile cancer, a history of cancer within the past two years, radical prostatectomy, and prior radiotherapy. The study was approved by the Bioethics Committee at Poznan University of Medical Sciences (resolution no. 110/21).

## Methods

The treatment cycle consisted of six Li-ESWT sessions performed every 5–12 days (on average once a week), with the following parameters: electrohydraulic source, average number of impulses: 6,725 (5,000–8,000 ± 960 impulses), average treatment time: 20 minutes, delivered via a BTL device.

The parameters were selected using the Motil algorithm [29] which considers the International Index of Erectile Function-5 (IIEF-5) score, the duration of symptoms, and patient comorbidities. All subjects ($n$ = 40) completed the full treatment cycle, with no drop-outs or adverse effects reported.

Patient assessments were conducted at three intervals: 1) before starting treatment ($n$ = 40), 2) at the end of the treatment cycle ($n$ = 40), and 3) six months after the

**Table 1.** Characteristics of the study group

| Variable | Number of subjects ($n$) | Mean | Median | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|
| **Age (years)** | 40 | 54.5 | 56 | 9.1 | 35 | 78 |
| **ED duration (years)** | 40 | 2.9 | 2 | 2.5 | 0.5 | 12 |
| **Number of Li-ESWT impulses** | 40 | 6725 | 7000 | 960.4 | 5000 | 8000 |
| ED – erectile dysfunction; Li-ESWT – low-intensity extracorporeal shock wave therapy | | | | | | |

**Table 2.** IIEF-5 scores before, immediately after, and six months after erectile dysfunction treatment

| Variable | Number of subjects ($n$) | Mean | Median | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|
| **IIEF-5 (pre-treatment) (pts)** | 40 | 12.6 | 12 | 3.9 | 6 | 20 |
| **IIEF-5 (post- treatment) (pts)** | 40 | 18 | 18 | 3.4 | 10 | 25 |
| **IIEF-5 (six months post-treatment) (pts)** | 21 | 18.9 | 20 | 4.1 | 9 | 24 |
| IIEF-5 – International Index of Erectile Function-5 | | | | | | |

**Table 3.** Statistical analysis of IIEF-5 scores before, immediately after, and six months after erectile dysfunction treatment

| Pairs of variables | *N* | T | Z | *p** level |
|---|---|---|---|---|
| **Pre-treatment IIEF-5 vs post-treatment IIEF-5** | 40 | 0.00 | 5.30 | 0.0000 |
| **Pre-treatment IIEF-5 vs IIEF-5 at six months post-treatment** | 21 | 0.00 | 3.82 | 0.0001 |
| **Post-treatment IIEF-5 vs IIEF-5 at six months post-treatment** | 21 | 0.00 | 2.33 | 0.0196 |

* Statistically significant results at $p < 0.05$ are underlined; IIEF-5 – International Index of Erectile Function-5

completion of treatment ($n = 21$) (the remaining subjects ($n = 19$) did not respond to follow-up contact) (tab. 2). The validated version of the IIEF-5 was used for the assessments. The IIEF-5 consists of five questions, each of which can be rated from 0 to 5 points (where '0' indicates the most severe impairment and '5' means no impairment) [30].

## Results

Statistica 9.0 was used to assess the results obtained. The analysis involved IIEF-5 scores recorded before and after treatment, as well as at a six-month follow-up (Wilcoxon Test; $p < 0.05$).

In the study group, the baseline IIEF-5 score averaged 12.6 ± 3.9 pts (6–20 pts). It increased to an average of 18.0 ± 3.4 pts (10–25 pts) upon treatment completion, and further to an average of 18.9 ± 4.1 (9–24 pts) at six months post-treatment (tab. 2). The observed increase was statistically significant in comparison to the pre-treatment ED status, both immediately following ED treatment and at the six-month follow-up (Wilcoxon Test, $p < 0.05$) (tab. 3).

The study evaluated the effects of age, ED duration, and the number of Li-ESWT impulses applied on IIEF-5 scores obtained before and after ED treatment, as well as at a six-month follow-up (Spearman's R test, $p < 0.05$). A negative correlation was observed between ED duration and patient scores both before treatment (−0.3526, $p < 0.05$ – moderate correlation), upon its completion (−0.0777, $p < 0.05$ – low correlation), and at six months post-treatment (−0.5180, $p < 0.05$ – high correlation). Additionally, a positive correlation was found between the pre-treatment versus post-treatment IIEF-5 scores (0.6113, $p < 0.05$ – high correlation) and six months after the treatment (0.5207, $p < 0.05$ – high correlation) (tab. 4).

No impact of the age of the patients on their IIEF-5 scores was observed before treatment, upon its completion, and six months post-treatment ($p > 0.05$). However, a negative correlation was noted between the number of Li-ESWT impulses and IIEF-5 scores obtained before (−0.6963, $p < 0.05$ – high correlation), immediately after (−0.5885, $p < 0.05$ – high correlation), and six months after the end of treatment (−0.6884, $p < 0.05$ – high correlation). This finding may be related to the fact that, according to the Motil therapeutic protocol, a greater number of Li-ESWT impulses were administered to patients in a poorer clinical condition. Consequently, the baseline severity of their condition influenced the final treatment outcomes (tab. 4).

## Discussion

Despite the observed positive effects of Li-ESWT in the treatment of ED, there are no conclusive guidelines with regard to treatment parameters and standards in various male populations [12–17, 21].

In 2012, Gruenwald et al. [12] conducted one of the first studies investigating the efficacy of Li-ESWT for ED in a group of 29 men (mean age: 61.3 years), who showed minimal response to PDE5i treatment (mean duration of erectile dysfunction: 5 years). After nine weeks of therapy (3,000 impulses per session, 2Hz, 0.09 mJ/mm$^2$) and one month of follow-up, a significant increase in IIEF scores was noted (8.8 points vs. 12.3 points after therapy) – without the use of pharmacotherapy. After another month, a further increase to 19.8 pts was recorded, following the administration of pharmacotherapy. No ad-

**Table 4.** Correlation analysis of the variables

| Spearman's R coefficient* | Age | ED duration | Number of Li-ESWT impulses | PDE5I | Pre-treatment IIEF-5 | Post-treatment IIEF-5 | IIEF-5 at 6 months post-treatment |
|---|---|---|---|---|---|---|---|
| **Age** | x | 0.2609 | 0.3887 | 0.1553 | −0.0882 | −0.2723 | −0.3464 |
| **ED duration** | 0.2609 | x | 0.4539 | 0.2010 | −0.3526 | −0.0777 | −0.5180 |
| **Number of Li-ESWT impulses** | 0.3887 | 0.4359 | x | 0.0870 | −0.6963 | −0.5885 | −0.6884 |
| **PDE5I** | 0.1553 | 0.2010 | 0.087 | x | 0.0371 | −0.0302 | −0.1852 |
| **Pre-treatment IIEF-5** | −0.0 | −0.3526 | −0.6963 | 0.0371 | x | 0.6113 | 0.5206 |
| **Post-treatment IIEF-5** | −0.2723 | −0.0777 | −0.5885 | −0.0302 | 0.6113 | x | 0.6241 |
| **IIEF-5 at 6 months post-treatment** | −0.3464 | −0.5180 | −0.6884 | −0.1852 | 0.0526 | 0.6241 | x |

* Statistically significant results at $p < 0.05$ are underlined
ED – erectile dysfunction; PDE5i – phosphodiesterase type 5 inhibitors; Li-ESWT – low-intensity extracorporeal shock wave therapy; IIEF-5 – International Index of Erectile Function-5

verse reactions were reported. In this study, one of the research tools used to assess EF improvement was the IIEF questionnaire. An abbreviated version of this questionnaire (IIEF-5) was also employed in our study.

Similar treatment parameters were applied by Pelayo-Nieto et al. [13], who investigated the effects of Li-ESWT in a group of 15 men (mean age 59.6 years). The improvement in EF was verified using the IIEF score, which changed significantly ($p$ <0.05) from 14.23 pts to 19.69 pts in 80% of patients. Four treatment sessions were conducted, once a week, with a wave energy of 0.09 mJ/mm$^2$, with 5,000 impulses per session. Similar clinical outcomes were obtained in our study, which demonstrated a significant improvement both immediately after therapy completion and at the six-month follow-up, compared to the baseline values (pre-treatment – 12.6 ± 3.9 pts, immediately after therapy – 18.0 ± 3.4 pts, at the six-month follow-up– 18.9 ± 4.1 pts). Our study followed a similar therapeutic regimen with one treatment/week for a total of six weeks.

Fojecki et al. [14] conducted a study in a group of 126 patients divided into a study group ($n$ = 63) and a control group receiving sham treatment ($n$ = 63). At the end of therapy, one month after the five-week treatment cycle ended, no significant differences were demonstrated between the two groups. The baseline IIEF scores in the sham and study groups were 10.9 pts and 11.5 pts, respectively. Four weeks after completing the five-week treatment, an increase in IIEF scores was observed (study group – 13.1 pts, control group – 13 pts), and after another four weeks, following the completion of another cycle, IIEF scores decreased in the study and control groups to 11.8 pts and 12.6 pts, respectively. This study yielded less promising results compared to those obtained in our analysis and in the studies by other authors cited above, which may be attributed to the use of planar shock wave therapy – a method less commonly applied for improving EF in men.

Palmieri et al. [15] analysed a group of men ($n$ = 109) suffering from ED, not responding to PDE5i. The authors administered 3,000 impulses with a power density of 0.25 mJ/mm$^2$ and a frequency of 4–6 Hz, twice a week for three weeks. Following treatment, a significant ($p$ <0.001) increase in IIEF scores was demonstrated (mean: 13.47 ± 4.61 pts vs 22.07 ± 5.27 pts; $p$ < 0.0001) after a one-month follow-up period. The treatment parameters used in their study, both in terms of power and frequency settings, were similar to those employed by our team (1.5b, 5 Hz), with a greater number of impulses (mean: 6,725) and twice as long treatment duration (six weeks).

Vinay et al. [16] investigated 76 men with ED responding poorly to PDE5i pharmacotherapy, who were divided into a study group ($n$ = 40, Li-ESWT) and a control group ($n$ = 36, sham treatment). In the study group, four Li-ESWT treatments (once a week; 5,000 impulses; 0.09 mJ/mm$^2$) were administered using an electromagnetic source. Following treatment, the median increase in IIEF values in the study and control groups was 3.5 and –0.5 ($p$ <0.05), respectively. The findings demonstrated that Li-ESWT, delivered via an electromagnetic source, provided a a modest therapeutic effect in patients poorly responding to pharmacotherapy. This therapy offers an alternative for patients rejecting more invasive therapies in the treatment of vascular ED.

It is vital to bear in mind that the beneficial effects of Li-ESWT have been highlighted not only in individual randomised controlled trials, but also in numerous meta-analyses. One such analysis, conducted by Kałka et al. [17], focused specifically on patients with diabetes and associated risk factors. The authors concluded that the application of Li-ESWT was beneficial, as reflected by a significant increase in EF. Nevertheless, they also highlighted that the observations were short-term and incomplete due to the lack of standardised therapeutic parameters, and therefore recommended further studies involving larger study groups.

Campbell et al. [31] summarised the results of seven randomised control trials (RCTs) conducted on a group of 607 patients, assessed using the IIEF and Erection Hardness Score (EHS). In their analysis, they observed significant heterogeneity among the groups and a low degree of accuracy in terms of both quality and quantity of the data (with inconsistencies in treatment protocols, a variety of equipment and treatment parameters). After a one-month follow-up, the IIEF score varied between 12.8–22.0 in the study group vs. 8.2–16.4 in the sham therapy group, showing a significant increase of 4.24 pts, ($p$ = 0.012). The authors concluded that Li-ESWT represented a safe therapeutic option in patients with vascular ED and could provide short-term effects. In our study, positive treatment effects persisted (and even improved) over a six-month follow-up period.

Capogrosso et al. [32] analysed 11 RCTs and 5 meta-analyses regarding the use of Li-ESWT in the treatment of uroandrological disorders, which were sourced from the Medline and Embase databases. They concluded that Li-ESWT was a non-invasive and safe treatment for ED and, through the available studies, presented questionable effects in terms of EF improvement due to high heterogeneity among the study groups. The authors emphasised the need for further multicentre studies involving larger groups of patients to clarify the efficacy of this treatment.

Bocchino et al. [33] reviewed 52 studies on the use of Li-ESWT in patients with vascular ED, diabetes mellitus, following pelvic floor surgery, as well as cases of undetermined aetiology. Therapeutic effects were determined with regard to improvement in the IIEF-5 index and EHS. The mean age of the patients was 55.87 ± 7.91 years, with an ED duration of 4.36 ± 2.08 years. The IIEF-5 score before therapy was 12.04 ± 2.67 pts, while three months after treatment completion it was 16.12 ± 5.72 pts. At six months, the score was 16.30 ± 3.26 pts, whereas one year after the treatment onset it was 16.85 ± 1.63 pts. EHS was 2.00 ± 0.46 pts at baseline, which increased to 2.58 ± 0.60 pts after three months of treatment, and amounted to 2.75 ± 0.46 pts after six months. After one year, a further increase to 2.87 ± 0.16 pts was observed (indicating an improvement in erectile rigidity sufficient for satisfactory sexual intercourse). These findings indicate that Li-ESWT represents a non-invasive and safe therapeutic alternative for well-counselled ED patients. Similarly to our study, none of the patients reported adverse effects.

Our study also analysed the impact of factors such as patient age, number of impulses applied, and ED duration. A negative correlation was found between ED duration and patient outcomes before (−0.3526, $p$ <0.05; moderate correlation), immediately after (−0.0777, $p$ <0.05; low correlation), and six months after treatment completion (−0.5180, $p$ <0.05; high correlation), which indicates that the earlier the treatment is initiated, in terms of the development of ED symptoms, the better the clinical outcomes.

Furthermore, a positive correlation was observed between the IIEF-5 scores before and after treatment (0.6113, $p$ <0.05; high correlation) and at the six-month follow-up (0.5207, $p$ <0.05; high correlation) (Spearman's R test, $p$ <0.05). This suggests that in terms of EF symptoms, the better the patient's condition prior to the treatment, the more favourable the prognosis and greater treatment efficacy.

Patient age showed no effect on the IIEF-5 scores before, after, or six months after the end of the treatment ($p$ >0.05). Moreover, in our study, we found no impact of age on therapeutic outcomes. This contrasts with the majority of scientific reports, which clearly indicate that EF impairment progresses with age [34]. Additionally, numerous authors emphasise that the effectiveness of ED treatment decreases with age due to the onset of cardiovascular comorbidities associated with the ageing process [35]. Thus, the evaluation of the therapeutic effects of Li-ESWT in the elderly requires further studies on larger patient groups.

Finally, a negative correlation was found between the number of Li-ESWT impulses and IIEF-5 scores obtained before (−0.6963, $p$ <0.05; high correlation), immediately after (−0.5885, $p$ <0.05, high correlation) and six months post-treatment (−0.6884, $p$ <0.05; high correlation). This may be due to the fact that, according to the treatment protocol, patients in poorer clinical condition received more Li-ESWT impulses.

## Conclusions

- Li-ESWT improves EF in patients suffering from ED.
- Positive EF scores, as assessed using the IIEF-5, were observed immediately after treatment completion and persisted at the six-month follow-up.
- A negative impact of ED duration on IIEF-5 scores was found before and after therapy, as well as six months after treatment.
- Patient age showed no impact on IIEF-5 scores following treatment and at the six-month follow-up.

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# STRATEGIC MEDICAL EVACUATIONS OF THE PERSONNEL OF POLISH MILITARY CONTINGENTS

## Strategiczne ewakuacje medyczne personelu Polskich Kontyngentów Wojskowych

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**Abstract**

**Introduction and objective:** Diseases and Non-Battle Injuries are the main reason for Strategic Medical Evacuations (STRATMEDEVAC) in Polish Military Contingents in Romania, Latvia, Kosovo, and Bosnia and Herzegovina. From 2021, there is no requirement for Polish soldiers to attend a health assessment by the Medical Evaluation Boards (MEB) before deployment to Polish Military Contingents in Europe or the NATO states. This study aimed to estimate the impact of the abolition of compulsory health assessments by the MEB on the number of STRATMEDEVAC and deaths in Polish Military Contingents. **Material and methods:** The analysis of medical evacuations of Polish soldiers performed in the years 2018–2019 (the period before the change in health assessment regulations) was compared to STRATMEDEVAC in 2022–2023 from Polish Military Contingents in Romania, Latvia, Kosovo, Bosnia and Hercegovina. **Results:** In 2022–2023, there was an increase in the incidence rate of losses in the category of Diseases and Non-Battle Injuries instigating STRATMEDEVAC (IRR = 2.07, $p$ = 0.006). There were not any statistically significant differences in either the category of Diseases (counted separately with the results: IRR = 1.58, $p$ = 0.26) or STRATMEDEVAC requiring a medical team with a dedicated aircraft (IRR = 1.23, $p$ = 0.66) or total mortality rate including all causes of death in Polish Military Contingents (IRR = 0.99, $p$ = 0.99). **Conclusions:** It is probable the preventive influence of soldiers' health assessments before deployment to military operations affects the rate of non-battle injuries. However, to estimate it, a detailed assessment of the individual certificates issued by the MEB must be conducted.

**Streszczenie**

**Wprowadzenie i cel:** Choroby i urazy niezwiązane z walką stanowią główną przyczynę strategicznej ewakuacji medycznej (ang. *strategic medical evacuations*, STRATMEDEVAC) personelu Polskich Kontyngentów Wojskowych stacjonującego w Rumunii, Łotwie, Kosowie oraz Bośni i Hercegowinie. Od 2021 r. polscy żołnierze, planowani do służby w Polskich Kontyngentach Wojskowych rozlokowanych w Europie lub w państwach NATO, nie są kierowani do wojskowych komisji lekarskich w celu określenia stanu zdrowia przed rozpoczęciem pełnienia zadań mandatowych poza granicami państwa. Celem pracy było oszacowanie wpływu braku określenia stanu zdrowia żołnierzy w wojskowych komisjach lekarskich na liczbę wykonanych STRATMEDEVAC oraz przypadków śmierci w Polskich Kontyngentach Wojskowych. **Materiał i metody:** Dokonano analizy porównawczej ewakuacji medycznych polskich żołnierzy zrealizowanych w latach 2018–2019 (okres przed zmianą przepisów o zniesieniu skierowań żołnierzy do wojskowych komisji lekarskich) z ewakuacjami w latach 2022–2023 z Polskich Kontyngentów Wojskowych w Rumunii, Łotwie, Kosowie oraz Bośni i Hercegowinie. **Wyniki:** W latach 2022–2023, w porównaniu z latami 2018–2019, nastąpił wzrost liczby strategicznych ewakuacji medycznych z powodu chorób i urazów niezwiązanych z walką (IRR = 2,07, $p$ = 0,006). Nie zanotowano istotnej statystycznie zmiany w osobno analizowanej kategorii chorób (IRR = 1,58, $p$ = 0,26) oraz STRATMEDEVAC z asystą medyczną w postaci zespołu ewakuacji medycznej (IRR = 1,23, $p$ = 0,66) oraz umieralności z powodu jakiejkolwiek przyczyny w Polskich Kontyngentach Wojskowych (IRR = 0,99, $p$ = 0,99). **Wnioski:** Istnieje prawdopodobieństwo prewencyjnego wpływu badań żołnierzy w wojskowych komisjach lekarskich przed wyjazdem do służby poza granicami państwa na częstość występowania urazów niezwiązanych z walką wśród uczestników Polskich Kontyngentów Wojskowych. Do oszacowania tego wpływu niezbędna jest szczegółowa ocena wydawanych przez wojskowe komisje lekarskie orzeczeń lekarskich.

**Keywords:** strategic medical evacuations; Military Evaluation Boards; Polish Military Contingents

**Słowa kluczowe:** strategiczna ewakuacja medyczna; wojskowe komisje lekarskie; Polskie Kontyngenty Wojskowe

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## Introduction

Polish Military Contingents (PMC) have a unique way of protecting the troops stationed abroad. While most elements of the medical readiness of levels 1 to 3 differ in each operation (most commonly it is a combination of own forces, international allied forces, and support of the hosting country), two tasks are always a national responsibility: strategic medical evacuations (STRATMEDEVAC) to Poland and treatment and rehabilitation on level 4 outside the theater of war. PMC Iraq is an exception, where the strategic medical evacuation may be conducted by both Polish Armed Forces to Poland, and by the allies to Ramstein Air Base in Germany. STRATMEDEVAC is a kind of medical evacuation from the operational area of responsibility to a home country or another safe location [1]. For this purpose, the Polish Armed Forces mainly use the C-295M CASA aircraft with a medical evacuation team (MET) (the team selection depends on the specific strategic medical evacuation). For the patients in the dependency category 4 (minimal dependency) [2] who are unable to continue due to health reasons but do not require medical supervision during air transport, hybrid solutions of Medical Evacuation (MEDEVAC) / Casualty Evacuation (CASEVAC) are in place. In this type of evacuation, transport to the airport and from the airport to a hospital in Poland is with medical supervision combined with a commercial flight or a standard PMC cargo or personnel flight.

Article 6 of the Act Changing the Act on Particular Solutions Connected with Prevention, Counteraction, and Fight against COVID-19, Other Infectious Diseases and Crisis Situations Caused by Them of 21st January 2021, and some other statutes limited the requirement of referring military personnel to the MEB before professional military service deployment to non-European countries and non-European countries which are not a State Party of the North Atlantic Treaty Organization (it was followed by entering the abovementioned provisions unchanged in Article 190(2)(5) of the Homeland Defence Act). It means that from 21st January 2021 in the following PMCs, the soldiers are not required to be sent to the MEB:

- PMC KFOR (Kosovo),
- PMC EUFOR (Bosnia and Herzegovina),
- PMC Latvia,
- PMC Romania,
- PMC IRINI (Sicily),
- PMC Turkey,
- PMC ORLIK (Lithuania, Estonia).

These are the following traditional types of casualties in Polish medical readiness doctrine [3]:

- killed in action (KIA),
- captured and missing in action (CMIA),
- wounded in action (WIA),
- battle stress (BS),
- disease and non-battle injuries (DNBI).

The DNBI category casualties are one of the major problems faced by medical planners during the preparation of the PMC or military training. The DNBI were the main reason for hospitalization during the Second World War, the Vietnam War, and both Gulf Wars [3–5]. Analogously, between 2001 and 2013 during the operation *Enduring Freedom* in Afghanistan, the incidence density (ID) for the strategic medical evacuation of the U.S. Forces personnel in the category of diseases, non-battle injuries, and battle injuries were 28.6/1000, 18.1/1000, and 12.0/1000 person-years respectively [6]. Slightly lower ID rates, still with the prevalence of the DNBI over wounded in action, were observed from 2003 to 2013 in the *Iraqi Freedom* and *New Dawn* operations for the strategic medical evacuation of the U.S. Forces personnel, i.e. 24.0/1000 person-years in the diseases category, 16.3/1000 person-years for the non-battle injuries, and 7.7/1000 person-years for the wounded in action [6–8]. In the data used for this research, the casualties in Polish Military Contingent in the years 2018–2019 and 2022–2023 consisted solely of the DNBI category and cases of death due to diseases which according to the doctrine [9] should be included in the died-on operations (DOO) category.

The objective of the research was to estimate the influence of the lack of health assessments of soldiers by the MEB on the number of performed STRATMEDEVAC and cases of death at the Polish Military Contingent.

## Materials and methods

A comparative analysis of Polish soldiers' medical evacuations in 2018–2019 (the period before the change of the regulations on referrals of soldiers to the Military Medical Boards) and the evacuations in 2022–2023 from Polish Military Contingents in Romania, Latvia, Kosovo (KFOR) and Bosnia and Herzegovina (EUFOR) was conducted. The years 2020–2021 were purposely disregarded to eliminate the influence of the COVID-19 pandemic, and due to the transitory nature of the regulations on obligatory MEB presence in 2021. The following contingents were not included in the analysis: PMC IRINI and PMC Turkey (due to the shortness of the missions), and PMC ORLIK (due to irregularity of the mission). The control group consisted of PMC IRAQ personnel who were still required to complete the health assess-

**Table 1.** Average number of military personnel in Polish Military Contingents (PMC) in the respective years and the number of person-years

| PMC | Average number of military personnel in 2018–2019 | Average number of military personnel in 2022–2023 | Number of person-years in 2018–2019 | Number of person-years in 2022–2023 |
|---|---|---|---|---|
| **Romania** | 220 | 225 | 440 | 450 |
| **Latvia** | 171 | 176 | 342 | 352 |
| **KFOR** | 253 | 247 | 506 | 494 |
| **EUFOR** | 43 | 48 | 86 | 96 |
| **Iraq** | 195 | 239 | 390 | 478 |

ments at the MEB (tab. 1). Each PMC rotation lasted 6 to 7 months, after which a replacement of staff flying from Poland would occur.

### Statistical methods

The statistical analysis was conducted using MedCalc Software Ltd. Comparison of two rates. https:/www.medcalc.org/calc/rate_comparison.php (Version 22.019, accessed February 2024). The result was presented as ID and the comparison of the population endangered by the lack of preventive influence of the MEB assessments in the years 2022–2023 with the not-endangered population in the years 2018–2019 was expressed as incidence rate ratio (IRR). For the IRR evaluation, a $Chi^2$ test was used, and the statistical validity level was established at $p < 0.05$. In the occurrence of the value '0', the IRR was not reported.

### Results

In the years 2018–2019 and 2022–2023, the following types of casualties resulted in the strategic medical evacuation (terminology according to Polish medical readiness doctrine [9]):

- diseases (D) – diseases including mental disorders such as acute reaction to stress and post-traumatic stress disorder (PTSD). Also, no battle injuries (BS) were noted in the analysis,
- non-battle injuries (NBI),
- died-on operations (DOO).

Additionally, in the D and NBI categories, the aircraft medical evacuations with the medical evacuation team (MET) were isolated and presented separately.

In PMC Romania, Latvia, EUFOR, and KFOR in 2022–2023 (the period after the abolition of referrals of soldiers to the MEB before commencing service in the Polish Military Contingent), the incidence density of casualties in the DNBI category increased in comparison to the years 2018–2019 (ID 30.17/1000 person-year vs. 14.56/1000 person-year, IRR = 2.07, $p = 0.006$).

Also, the incidence density increased separately in the NBI category (ID 18.68/1000 person-year in 2022–2023 *vs* ID 7.28/1000 person-year in 2018–2019, IRR = 2.57, $p = 0.008$). No statistically significant changes in incidence density in the DNBI subcategory instigating a strategic medical evacuation with a MET with a specialist aircraft, or in the D category instigating a general strategic military evacuation or a strategic military evacuation with a MET with a specialist aircraft. In the D category, there were 2 cases of mental disorders, reaction to stress or PTSD in the interview (in PMC KFOR in 2018 and PMC Romania in 2023) (tab. 2).

In PMC Romania in 2022–2023, the incidence density of casualties in the DNBI category instigating a STRATMEDEVAC was 33.33/1000 person-years, and in 2018–2019 it was 29.55/1000 person-years. At the same time, no statistically significant change in the incidence density of casualties was observed in the DNBI, D, and NBI categories instigating a STRATMEDEVAC (tab. 3).

Among the researched PMCs, the incidence density of casualties in the DNBI category instigating a strategic medical evacuation in 2022–2023 in comparison to 2018–2019 was in PMC Latvia (incidence density ID 51.14/1000 person-years vs. ID 8.77/1000 person-years, IRR = 5.83, $p = 0.001$). The incidence density also increased in the separate NBI category (ID 34.09/1000 person-years vs. ID 8.77/1000 person-years, IRR = 3.89, $p = 0.024$). No statistically significant changes in incidence density in the DNBI category instigating a STRATMEDEVAC with a MET with a specialist aircraft, or in the D category instigating a general strategic medical evacuation and STRATMEDEVAC with a MET with a specialist aircraft (tab. 4).

In PMC KFOR in 2022–2023, the incidence density of casualties in the DNBI category that instigated a STRATMEDEVAC was 14.17/1000 person-years and, in 2018–2019 was 5.93/1000 person-years. At the same time, there were not any statistically significant changes in incidence density in the DNBI, D, and NBI categories that instigated a STRATMEDEVAC (tab. 5).

**Table 2.** STRATMEDEVAC from Polish Military Contingents Romania, Latvia, EUFOR, and KFOR in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 20 (14 .56/1000 person-years) | 42 (30.17/1000 person-years) | 2.07 ($p = 0.006$) |
| | **With the use of the MET** | 8 (5.82/1000 person-years) | 10 (7.18/1000 person-years) | 1.23 ($p = 0.66$) |
| **STRATMEDEVAC due to D** | **Total** | 10 (7.28/1000 person-years) | 16 (11.49/1000 person-years) | 1.58 ($p = 0.26$) |
| | **With the use of the MET** | 6 (4.37/1000 person-years) | 4 (2.87/1000 person-years) | 0.66 ($p = 0.54$) |
| **STRATMEDEVAC due to NBI** | **Total** | 10 (7.28/1000 person-years) | 26 (18.68/1000 person-years) | 2.57 ($p = 0.008$) |
| | **With the use of the MET** | 2 (1.46/1000 person-years) | 6 (4.31/1000 person-years) | 2.96 ($p = 0.18$) |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

In PMC EUFOR in 2022–2023, the incidence density of casualties in the DNBI category instigating a STRATMEDEVAC was 20.83/1000 person-years and, in 2018–2019 was 11.36/1000 person-years. At the same time, there were not any statistically significant changes in incidence density in the DNBI, D, and NBI categories that instigated a STRATMEDEVAC (tab. 6).

In PMC IRAQ (the control group) in 2022–2023, the incidence density of casualties in the DNBI category instigating a STRATMEDEVAC was 12.55/1000 person-years and, in 2018–2019 was 15.38/1000 person-years. At the same time, there were not any statistically significant changes in incidence density in the DNBI, D, and NBI categories instigating a STRATMEDEVAC. In the D category, a case of mental disorder, reaction to stress, or PTSD in the interview was accounted (2023) (tab. 7).

There were not any statistically significant changes in mortality rate due to all causes of death in PMC Romania, Latvia, KFOR, and EUFOR in 2022–2023 in comparison to 2018–2019 (tab. 8).

There were not any occurrences of death of Polish soldiers in the control group (PMC Iraq) in 2018–2019 and 2022–2023.

The incidence density of casualties in the DNBI category instigating a STRATMEDEVAC in PMC Romania, Latvia, KFOR, and EUFOR increased after the referral of soldiers for health assessments by the MEB was relinquished (IRR = 2.07, $p = 0.006$). However, the author finds the direct connection between the increase and the lack of preventive influence of the MEB is debatable as it is caused mainly by the increased number of the NBIs (IRR = 2.57, $p = 0.0085$), not by the D category, for which the increase was statistically insignificant (IRR = 1.58, $p = 0.26$), and on which the MEB could have a preventive influence, e.g. elimination of soldiers with chronic disorders. The mortality rate with all causes of death did not increase in the researched PMCs in 2022–2023 in comparison to 2018–2019 (RR = 0.99, $p = 0.99$). No statistically significant increase occurred in the incidence density of casualties in the DNBI category instigating a strategic military evacuation with MET with

**Table 3.** STRATMEDEVAC from Polish Military Contingent Romania in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 13 (29.55/1000 person-years) | 15 (33.33/1000 person-years) | 1.13 ($p = 0.75$) |
| | **With the use of the MET** | 5 (11.36/1000 person-years) | 7 (15.56/1000 person-years) | 1.37 ($p = 0.61$) |
| **STRATMEDEVAC due to D** | **Total** | 6 (13.64/1000 person-years) | 7 (15.56/1000 person-years) | 1.14 ($p = 0.82$) |
| | **With the use of the MET** | 3 (6.82/1000 person-years) | 3 (6.67/1000 person-years) | 0.98 ($p = 0.98$) |
| **STRATMEDEVAC due to NBI** | **Total** | 7 (15.91/1000 person-years) | 8 (17.78/1000 person-years) | 1.12 ($p = 0.84$) |
| | **With the use of the MET** | 2 (4.54/1000 person-years) | 4 (8.89/1000 person-years) | 1.96 ($p = 0.47$) |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

**Table 4.** STRATMEDEVAC from Polish Military Contingent Latvia in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 3 (8.77/1000 person-years) | 18 (51.14/1000 person-years) | 5.83 ($p = 0.001$) |
| | **With the use of the MET** | - | 1 (2.84/1000 person-years) | - |
| **STRATMEDEVAC due to D** | **Total** | - | 6 (17.05/1000 person-years) | - |
| | **With the use of the MET** | - | - | - |
| **STRATMEDEVAC due to NBI** | **Total** | 3 (8.77/1000 person-years) | 12 (34.09/1000 person-years) | 3.89 ($p = 0.024$) |
| | **With the use of the MET** | - | 1 (2.84/1000 person-years) | - |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

**Table 5.** STRATMEDEVAC from Polish Military Contingent KFOR in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 3 (5.93/1000 person-years) | 7 (14.17/1000 person-years) | 2.39 ($p = 0.21$) |
| | **With the use of the MET** | 2 (3.95/1000 person-years) | 1 (2.02/1000 person-years) | 0.51 ($p = 0.64$) |
| **STRATMEDEVAC due to D** | **Total** | 3 (5.93/1000 person-years) | 2 (4.05/1000 person-years) | 0.68 ($p = 0.71$) |
| | **With the use of the MET** | 2 (3.95/1000 person-years) | - | - |
| **STRATMEDEVAC due to NBI** | **Total** | - | 5 (10.12/1000 person-years) | - |
| | **With the use of the MET** | - | 1 (2.02/1000 person-years) | - |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

**Table 6.** STRATMEDEVAC from Polish Military Contingent EUFOR in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 1 (11.36/1000 person-years) | 2 (20.83/1000 person-years) | 1.79 ($p = 0.69$) |
| | **With the use of the MET** | 1 (11.36/1000 person-years) | 1 (10.42/1000 person-years) | 0.90 ($p = 0.95$) |
| **STRATMEDEVAC due to D** | **Total** | 1 (11.36/1000 person-years) | 1 (10.42/1000 person-years) | 0.90 ($p = 0.95$) |
| | **With the use of the MET** | 1 (11.36/1000 person-years) | 1 (10.42/1000 person-years) | 0.90 ($p = 0.95$) |
| **STRATMEDEVAC due to NBI** | **Total** | - | 1 (10.42/1000 person-years) | - |
| | **With the use of the MET** | - | - | - |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

**Table 7.** STRATMEDEVAC from Polish Military Contingent Iraq in 2018–2019 and 2022–2023

| Type of evacuation | | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|---|
| **STRATMEDEVAC due to DNBI** | **Total** | 6 (15.38/1000 person-years) | 6 (12.55/1000 person-years) | 0.82 ($p = 0.73$) |
| | **With the use of the MET** | 1 (2.56/1000 person-years) | 1 (2.09/1000 person-years) | 0.82 ($p = 0.90$) |
| **STRATMEDEVAC due to D** | **Total** | 4 (10.26/1000 person-years) | 3 (6.28/1000 person-years) | 0.61 ($p = 0.54$) |
| | **With the use of the MET** | 1 (2.56/1000 person-years) | 1 (2.09/1000 person-years) | 0.82 ($p = 0.90$) |
| **STRATMEDEVAC due to NBI** | **Total** | 2 (5.13/1000 person-years) | 3 (6.28/1000 person-years) | 1.22 ($p = 0.85$) |
| | **With the use of the MET** | - | - | - |

D – diseases; DNBI – disease and non-battle injuries; ID – incidence density; IRR – incidence rate ratio; NBI – non-battle injuries; STRATMEDEVAC – strategic medical evacuation; MET – medical evacuation team

**Table 8.** Number of deaths in Polish Military Contingents (PMC) Romania, Latvia, KFOR, and EUFOR in 2018–2019 i 2022–2023

| | 2018–2019 (ID) | 2022–2023 (ID) | IRR (*p*) |
|---|---|---|---|
| **Number of deaths in PMC** | 1 (0.73/1000 person-years) | 1 (0.72/1000 person-years) | 0.99 (*p* = 0.99) |
| ID – incidence density; IRR – incidence rate ratio | | | |

a specialist aircraft (RR = 1.23, *p* = 0.67). It is an important factor due to the high cost borne by the Armed Forces during this type of evacuation.

## Commentary

In the study conducted, losses from the NBI category accounted for the majority of the reasons for STRATMEDEVAC of the Polish Armed Forces personnel stationed in PMC Romania, Latvia, Kosovo, and Bosnia and Herzegovina, 50% in 2018–2019 and 62% in 2022–2023, respectively. These data do not coincide with U.S. Forces Health Service data for soldiers serving in Operation *Enduring Freedom* in Afghanistan (31% of losses), and *Iraqi Freedom* and *New Dawn* in Iraq (34% of losses) [6–8]. Analogous data comes from French sources, where STRATMEDEVAC among French Armed Forces personnel participating in operations in Lebanon, Afghanistan and Côte d'Ivoire for losses in the NBI category was 38% [10]. Key to understanding this discrepancy may be the same article, which indicated that in non-combat operations the incidence of NBI increases significantly in the absence of STRATMEDEVAC for evacuations from the WIA category [10]. Similarly, in PMC, there were no evacuations from the WIA category in the years analyzed mainly due to the relatively safe military situation in the theater of operations involving Polish soldiers. A study by Hall et al. [11] analyzed STRATMEDEVAC due to DNBI from 2017–2021 in USCENTCOM and USAFRICOM-led operations. Evacuations from the NBI category accounted for 18% for USCENTCOM and 15% for USAFRICOM, respectively. Evacuations for psychiatric reasons accounted for as much as 27% in USCENTCOM operations and 12% in USAFRICOM operations. In the same study, the incidence of sanitary losses from the DNBI category was 1.0–5.2/1000 person-months for USAFRICOM and 1.1–2.8/1000 person-months for USCENTCOM. While the results in the analyzed PMCs fall within the above ranges (incidence in 2022–2023 of 30.17/1000 person-years vs. 14.56/1000 person-years in 2018–2019), the results for STRATMEDEVAC for psychiatric reasons in the PMCs are completely different (5% in 2018–2019 vs. 2.4% in 2022–2023), which can be explained by the less onerous service conditions of Polish soldiers. In a publication on the qualification of U.S. Forces soldiers for military service, the authors point out that U.S. medical boards often issue negative rulings for those with a history of injuries and specialized treatment related to musculoskeletal injuries [12]. Meanwhile, another study found that during service recruitment, 4% of active personnel may not be referred for surgery due to musculoskeletal injuries, accounting for as much as 65% of all reasons for soldiers' inability to serve in the theater of operations [13]. It can be assumed that there are similar health problems for soldiers in the Polish Armed Forces related to musculoskeletal injuries, and at the same time, due to the abolition of the obligation to assess the health of soldiers in the MEB before they are sent to serve in the PMC, personnel are being sent to the area of military operations who, burdened by medical history, may weaken the combat capability of their own troops and contribute to an increase in medical evacuations to the country due to NBI resulting from the injuries that occur. Unfortunately, the lack of statistical data on negative medical certificates issued by the MEB limits the ability to estimate the scale of the problem.

## Conclusions

There is likely to be a preventive influence of the examination of soldiers by the MEB prior to their deployment for service abroad on the incidence of non-combat-related injuries among PMC participants. A detailed assessment of the medical certificates issued by the MEB is needed to estimate this impact. The Polish Armed Forces have a responsibility for prevention, including the duty to provide a safe service environment and to educate soldiers serving in the PMC on injury prevention during duty assignments and sports.

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# THE QUALITY OF PULMONARY DIAGNOSIS IN PATIENTS WITH LUNG CANCER QUALIFIED FOR THORACIC SURGERIES

## Jakość diagnostyki pulmonologicznej u pacjentów z guzem płuca kwalifikowanych do procedur torakochirurgicznych

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**Abstract**

**Introduction and objective:** Lung cancer is diagnosed in most cases at a late stage. Primary diagnosis of patients takes place in pulmonology departments. More effective primary diagnosis through cooperation with thoracic surgery and oncology departments appears to be the key to better treatment outcomes. **Objective:** The aim of this article was to assess the value of diagnosis performed in the Department of Pulmonology in terms of determining the aetiology and stage of lung cancer and qualifying for thoracic surgical diagnostic and therapeutic procedures. **Materials and methods:** The study included 51 patients with lung cancer detected in imaging tests, who, following a series of diagnostic tests performed in the Department of Pulmonology, e.g. bronchofiberoscopy, fine-needle aspiration biopsy, cytology of the pleural fluid, spirometry, diffusing capacity of the lungs for carbon monoxide, and laboratory tests, were referred to the Department of Thoracic Surgery for radical treatment or complementary invasive diagnosis. **Results:** The efficacy of pulmonological diagnostic tests in detecting malignancies in the study group was found to be relatively high, with sensitivity of 0.66, specificity of 0.81, and accuracy of 0.71. As a result, radical surgery could be performed in 24 patients (47.06%). Thoracic surgical diagnostic procedures allowed for total lung tumour resection in another 7 patients. In total, 31 patients underwent optimal lung resection(60.78%). **Conclusions:** Cooperation of the Department of Pulmonology with complementary thoracic surgical diagnostic tests allows for precise determination of the aetiology of lung cancer and implementing therapeutic surgeries in technically resectable cancers.

**Streszczenie**

**Wprowadzenie i cel:** Rak płuca w większości przypadków jest rozpoznawany w późnym stadium choroby. Wstępna diagnostyka pacjentów odbywa się na oddziałach o profilu pulmonologicznym. Poprawa jej skuteczności i współpraca z torakochirurgami oraz onkologami wydaje się być kluczem do poprawy wyników leczenia. Celem artykułu jest ocena wartości diagnostyki przeprowadzonej na oddziale pulmonologicznym w aspekcie ustalenia etiologii i zaawansowania guza płuca oraz kwalifikacji do torakochirurgicznych procedur diagnostycznych i leczniczych. **Materiał i metody:** Oceną objęto 51 pacjentów z guzem płuca wykrytym w badaniach obrazowych, którzy po wykonaniu na oddziale pulmonologii badań diagnostycznych obejmujących bronchofiberoskopię, biopsję transtorakalną, badanie cytologiczne płynu z opłucnej, spirometrię, badanie zdolności dyfuzyjnej płuc dla tlenku węgla i badania laboratoryjne zostali skierowanych na oddział torakochirurgii w celu przeprowadzenia leczenia radykalnego lub uzupełniającej diagnostyki inwazyjnej. **Wyniki:** Jakość diagnostyki pulmonologicznej w wykrywaniu nowotworu złośliwego w badanej grupie okazała się stosunkowo wysoka (czułość: 0,66, swoistość: 0,81, dokładność: 0,71). Dzięki temu u 24 pacjentów (47,06%) możliwe było wykonanie operacji radykalnej. Po uwzględnieniu diagnostycznych procedur torakochirurgicznych doszczętne usunięcie guza płuca wykonano u kolejnych 7 chorych. Łącznie u 31 pacjentów przeprowadzono optymalne zabiegi resekcyjne płuca (60,78%). **Wnioski:** Współpraca oddziału pulmonologii w połączeniu z uzupełniającą diagnostyką torakochirurgiczną pozwala na dokładne ustalenie etiologii guza płuca oraz wykonanie operacji terapeutycznych w nowotworach technicznie resekcyjnych.

**Keywords:** lung cancer; bronchofiberoscopy; VATS; fine needle aspiration biopsy

**Słowa kluczowe:** rak płuca; bronchofiberoskopia; VATS; biopsja aspiracyjna cienkoigłowa

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## Introduction

Primary lung cancer (PLC) is the second most common malignancy worldwide (2.2 million cases in 2020) [1]. However, it is responsible for the highest rates of cancer mortality in both women and men (approximately 18%), with a 5-year survival rate of 7–25%, which is lower than for many other cancers [2].

PLC is initially clinically asymptomatic, with no concerns raised until symptoms appear in the late stage of disease, when the tumour causes narrowing of large bronchi, affects mediastinal structures, or when distant metastases appear and it is too late for surgical intervention. Almost 46.6% of patients have clinical stage IV at diagnosis, and interestingly, almost 50% of them present only one or two symptoms [3]. The most optimal therapeutic outcomes are achieved at an early stage of the disease. In the case of non-small cell lung cancer (NSCLC), radical resection of the tumour along with regional lymph nodes is considered most effective, which is possible at stages I, II and IIIA [4, 5].

Naturally, efforts are made to improve the diagnostic efficacy through early detection, as well as PLC grading and staging in order to select the optimal treatment approach.

Initial diagnosis in LC patients is usually performed in pulmonology departments. Imaging modalities, such as computed tomography (CT) [6] and less accessible positron emission tomography (PET) [7, 8], allow to determine the size and location of the tumour, the presence of hilar and mediastinal lymphadenopathy, and distant metastases. Routine diagnostic tests used to determine the aetiology of the tumour include bronchofiberoscopy (FOB) with histopathological specimen collection [9, 10], endobronchial ultrasound-guided transbronchial biopsy of the mediastinal nodes or the tumour itself (EBUS-TBNA) [11]. In patients with peripheral tumours, cytological diagnosis can be obtained with transthoracic fine needle aspiration biopsy (FNAB) [12] or core needle biopsy [13]. Pulmonary function tests (PFTs) using spirometry, scintigraphy and diffusing capacity of the lungs for carbon monoxide (DLCO) [14], as well as a history of comorbidities are important elements of complementary pulmonary diagnosis. Patients with less advanced tumours, who are in good general condition and meet the appropriate respiratory function criteria are qualified for surgical treatment. In some patients, pulmonary diagnosis does not allow determining the aetiology of the tumour. Such patients are usually referred for further diagnosis in the Department of Thoracic Surgery, where it is possible to perform minimally invasive procedures, such as mediastinoscopy [15], core needle biopsy, Daniels biopsy [16], and video-assisted thoracoscopic surgery (VATS), which, apart from its diagnostic role, may in some cases allow for simultaneous radical resection of the tumour [17, 18].

## Current model of diagnostic and therapeutic management in the Department of Pulmonology

A specialist from the Department of Pulmonology of the Provincial Health Care Centre For The Treatment Of Lung Diseases And Rehabilitation in Łódź consults patients who are referred to the hospital from three sources: primary care clinics, specialist lung disease clinics and other hospital centres. At this stage, decisions are made about both further diagnostic path and qualification for invasive diagnostic procedures in the Department of Pulmonology. Patients with comorbidities often additionally require appropriate treatment or modification of their current therapy. After an individual assessment of cardiovascular (CV) risk in an LC patient, based on medical history and electrocardiography, PFTs are performed for ventilatory disorders. Imaging modalities are also done as a standard unless they had been performed earlier. CT is of particular importance. Additionally, abdominal ultrasound (US) is performed if necessary, and if the presence of pleural fluid is suspected, chest US with pleural puncture (thoracentesis) is done, with the evacuated fluid sent for general, bacteriological and cytological analyses. The next diagnostic step at the Department of Pulmonology is to perform invasive investigations, such as bronchofiberoscopy (FOB) and percutaneous FNAB of the lung tumour. Patients who require improvement of their clinical condition receive individualised optimal treatment. Then, patients who qualify for surgery or require more in-depth diagnosis are consulted by a thoracic surgeon from a cooperating centre from the Department of Thoracic Surgery, General and Oncological Surgery of the University Clinical Hospital of the Military Medical Academy.

## Aims

- Evaluation of selected clinical parameters, as well as cytological and histopathological diagnosis in patients with LC detected in imaging during hospital stay in the Department of Pulmonology.
- Assessment of the quality of the diagnostic process conducted at the Department of Pulmonology in terms of determining the aetiology and stage of LC.
- Evaluation of the efficacy of combined pulmonary and thoracic surgery diagnosis in the qualification of LC patients for optimal treatment.

## Materials and methods

The study group consisted of 74 patients initially diagnosed in the Department of Pulmonology due to radiological suspicion of LC. Men and women accounted for

54.1% (*n* = 40, age 44–75 years) and 45.9% (*n* = 34, age 26–76 years) of the study group, respectively. All patients underwent diagnostic procedures including FOB, FNAB, cytology of pleural fluid and complementary investigations, including spirometry, laboratory workup, DLCO (some patients), etc.

After completing pulmonary diagnosis, a thoracic surgery consultation was done. Patients with an established histopathological diagnosis of NSCLC and a specific staging based on the TNM classification were referred for radical surgery. The remaining patients with cancer of unspecified aetiology were qualified for complementary invasive thoracic surgery diagnosis. Ultimately, 51 patients, who were referred for radical treatment or invasive diagnostic procedures at the Department of Thoracic Surgery following pulmonological diagnosis, were qualified for statistical analysis, which enabled a comparison of the efficacy of cytological and histopathological tests from both centres.

**Statistical analysis**

Statistical calculations were performed using Statistica ver. 12 (StatSoft, USA) and Excel. The Shapiro-Wilk W test was used to verify whether the quantitative variable came from a population with a normal distribution. The Leven's (Brown-Forsythe) test was used to verify the hypothesis of equal variances. The significance of differences between two groups (model of unrelated variables) was assessed using the Student's t-test (or the Welch test in the case of lack of homogeneity of variances) or the Mann-Whitney U test (if the conditions of applicability of the Student's t-test were not met or for variables measured on an ordinal scale).

In the case of statistically significant differences between groups, post hoc tests were used (Tukey's test for F, Dunn's test for Kruskal-Wallis). Chi-square tests of independence were employed for qualitative variables (with Yates' correction for cell counts below 10, checking Cochran's conditions, Fisher's exact test, respectively). In order to determine the relationship, strength and direction between variables, correlation analysis was used, calculating Pearson's and/or Spearman's correlation coefficients. In all calculations, the level of significance was assumed at $p = 0.05$.

When evaluating the outcomes of diagnostic and therapeutic procedures used in the Department of Thoracic Surgery, statistical studies were conducted using the Statgraphics Centurion 18 ver. 18.1.12 (Statgraphics Technologies Inc., USA). Qualitative variables were tested using the Chi$^2$ test of independence (i.e. $\chi^2$). The level of statistical significance was $p < 0.05$.

**Quality assessment of pulmonological diagnostic procedures in LC**

*Diagnostic procedures in the Department of Pulmonology*

The study group consisted of 51 patients with LC detected on imaging, including 28 women and 23 men. The age of patients ranged from 51 to 81 years (mean: 66.96 ± 7.95 years).

Diagnostic tests were run in the Department of Pulmonology to determine LC aetiology (fig. 1, tab. 1).

Imaging was performed in 98.6% of patients. No repeat CT was performed in patients with up-to-date outpatient results (not older than one month). The most important investigations were those used to collect tumour specimens for pathomorphological evaluation, including cytology and histopathology. Among these, endoscopic diagnostic procedures (mainly FOB) and transthoracic FNAB of the lung were performed in 71.6% and 56.8% of patients, respectively.

Other diagnostic modalities were used to assess patients' general condition, respiratory function and to identify comorbidities. Among these, spirometry assessment of pulmonary function, which was performed in 60.8% of patients, was the primary test. Assessment of the circulatory system was performed in 95.9% of patients. In the Department of Pulmonology, all patients (100%) underwent microbiological tests focused primarily on infections with non-specific and specific microbes (tuberculosis and non-tuberculosis mycobacteria). Seven patients

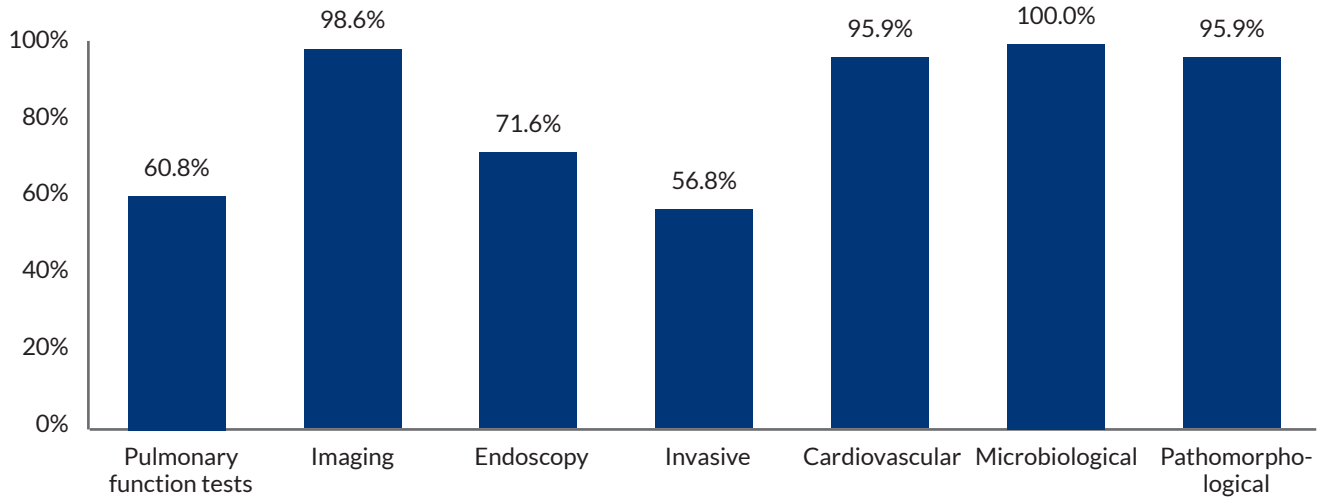



**Figure 1.** Diagnostic investigations performed at Department of Pulmonology

**Table 1.** Summary of imaging tests performed at the Department of Pulmonology

| Diagnostic imaging | Group (*n* =74) |
|---|---|
| Chest X-ray | 61 (82.4%) |
| Abdominal US | 36 (48.6%) |
| Chest US | 16 (21.6%) |
| Chest CT | 61 (82.4%) |
| Abdominal CT | 0 (0.0%) |

**Table 2.** Suspected etiology of nodular lesions based on radiological examinations performed at the Department of Pulmonology

| Tumour type | Group (*n* = 57) |
|---|---|
| Unknown aetiology | 25 (43,9%) |
| Malignant | 20 (35,1%) |
| Infections, inflammatory and granulomatous lesions | 10 (17,5%) |
| Benign | 2 (3,5%) |

(9.45%) from the initial study group were ultimately disqualified from invasive procedures due to the advanced stage of the disease, and received conservative treatment instead, while 16 patients (21.6%) were discharged home after completing the diagnosis.

### Imaging findings in patients with LC

The following preliminary diagnoses were made in the study group based on radiological findings (tab. 2): suspected malignancy in 20 (35.1%) patients, suspected cancer of unspecified origin in 25 (43.9%) patients, inflammatory and granulomatous lesions or infections in 10 (17.5%) patients. Suspicious benign lesions were found in 2 patients (3.5%). Based on imaging in the Department of Pulmonology, proliferative lung process was suspected in 47 (63.5%) patients. Out of 61 CT scans performed in this centre, the detected lesions did not meet LC radiological criteria in 4 cases.

### Endoscopic investigations performed in the Department of Lung Diseases

A total of 54 patients were qualified for endoscopic diagnosis in the Department of Pulmonology, including FOB in 53 (71.6% of the total study group). Gastroscopy was additionally performed in 1 LC patient due to dysphagia.

### Invasive investigations performed in the Department of Pulmonology

In addition to endoscopic investigations, other invasive procedures were also performed (fig. 2). Peripheral tumour location within the chest allowed for obtaining specimens for microscopic cytology by means of biopsy of the lung tumour through the chest wall. It was performed in 44.6% of patients. Pleural puncture was performed in 16.2% of patients as an adjuvant to cytological, microbiological and biochemical diagnosis.

### Invasive findings in LC patients admitted to the Department of Pulmonology

The diagnostic efficacy for malignancies based on 53 FOBs with specimen collection for histopathology or bronchial brushing (tab. 3) was 35.8%. Transthoracic biopsy of LC was performed in 33 patients, reaching cytological diagnosis of malignancy in 39.4% of cases. Pleural puncture was performed in 12 patients, with the rates of cytological malignant diagnoses of 8.0%. There were no statistically significant differences in the diagnostic efficacy for LC between FOB and lung biopsy ($p$ = 0.7409). Similarly, there were no statistically significant differences in the diagnostic efficacy between FOB and pleural puncture ($p$ = 0.0622). FNAB of the lung tumour was

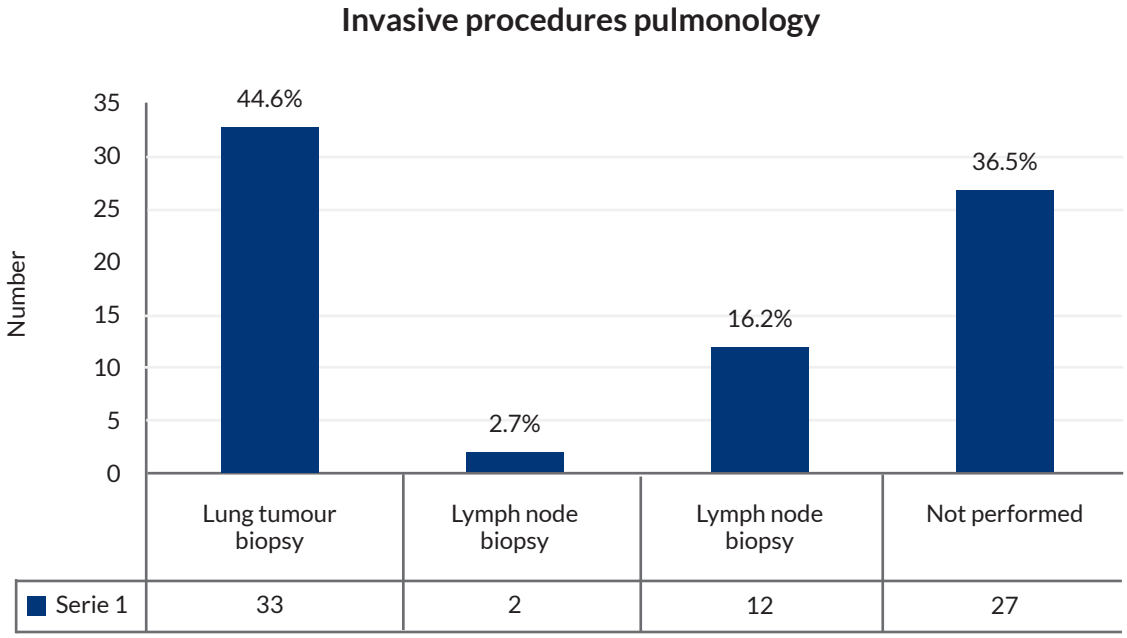



**Figure 2.** Invasive investigations performed at Department of Pulmonology

a significantly more effective diagnostic approach for malignancies compared to pleural puncture ($p = 0.0466$).

### LC aetiology in invasive investigations in the Department of Pulmonology

Pathomorphological investigations performed in the Department of Pulmonology in LC patients, including cytology and histopathology, revealed the following diagnostic categories (tab. 4): no cancer cells ($n = 33$, 44.6%), NSCLC ($n = 21$, 28.4%), squamous cell carcinoma ($n = 9$, 12.2%), adenocarcinoma ($n = 4$, 5.4%), cells with features of atypia/unspecified neoplastic cells ($n = 5$, 6.8%), pleural mesothelioma type cells ($n = 2$, 2.7%), small cell carcinoma ($n = 1$), large cell carcinoma ($n = 1$), and additionally features of inflammation and dysplasia ($n = 11$, 14.9%). Of all diagnoses obtained in pathological examinations, malignant neoplasm was suspected in 43 patients (fig. 3), accounting for 58.1% of all LC patients.

### Pulmonary function tests

Pulmonary function tests (PFTs) are one of the key elements of patient qualification for elective invasive procedures in the Department of Pulmonology. Spirometry was performed in 45 (60.8%) patients (tab. 5).

Normal spirometric parameters were found in 16 (35.6%) of these patients. Findings indicating obstructive ventilatory disorders were observed in 28.9% of patients, including moderately severe disorders in 20.0%. Restrictive ventilatory disorders were found in about 13.3% of patients. Plethysmography, as an extension of PFT in patients with suspected restrictive disorders, was performed in 3 (4.1%) patients.

### Assessment of selected factors influencing the diagnostic value in the Department of Pulmonology

Univariate and multivariate logistic regression models were performed (tab. 6) to assess the impact of the diagnostic process in the Department of Pulmonology on determining LC aetiology.

All parameters were statistically insignificant in the univariate logistic regression model, while only one parameter (spirometry) was statistically significant ($p = 0.0485$) in the multivariate logistic regression model. Spirometric detection of ventilatory disorders resulted in a reduced likelihood of diagnosing malignancy in masses detected with imaging due to limited respiratory capacity and the risk associated with more aggressive invasive procedures.

### Summary of diagnostic approaches for identifying LC aetiology in the Department of Pulmonology

Three basic invasive procedures were used to determine LC origin in the Department of Pulmonology. Cytological or histopathological findings are presented in figure 4. Malignant cells were detected in 35.29% with bronchofiberoscopy, 38.46% with FNAB, and in 8.33% of cases with cytology.

**Table 3.** Diagnosis of LC based on invasive tests performed at the Department of Pulmonology

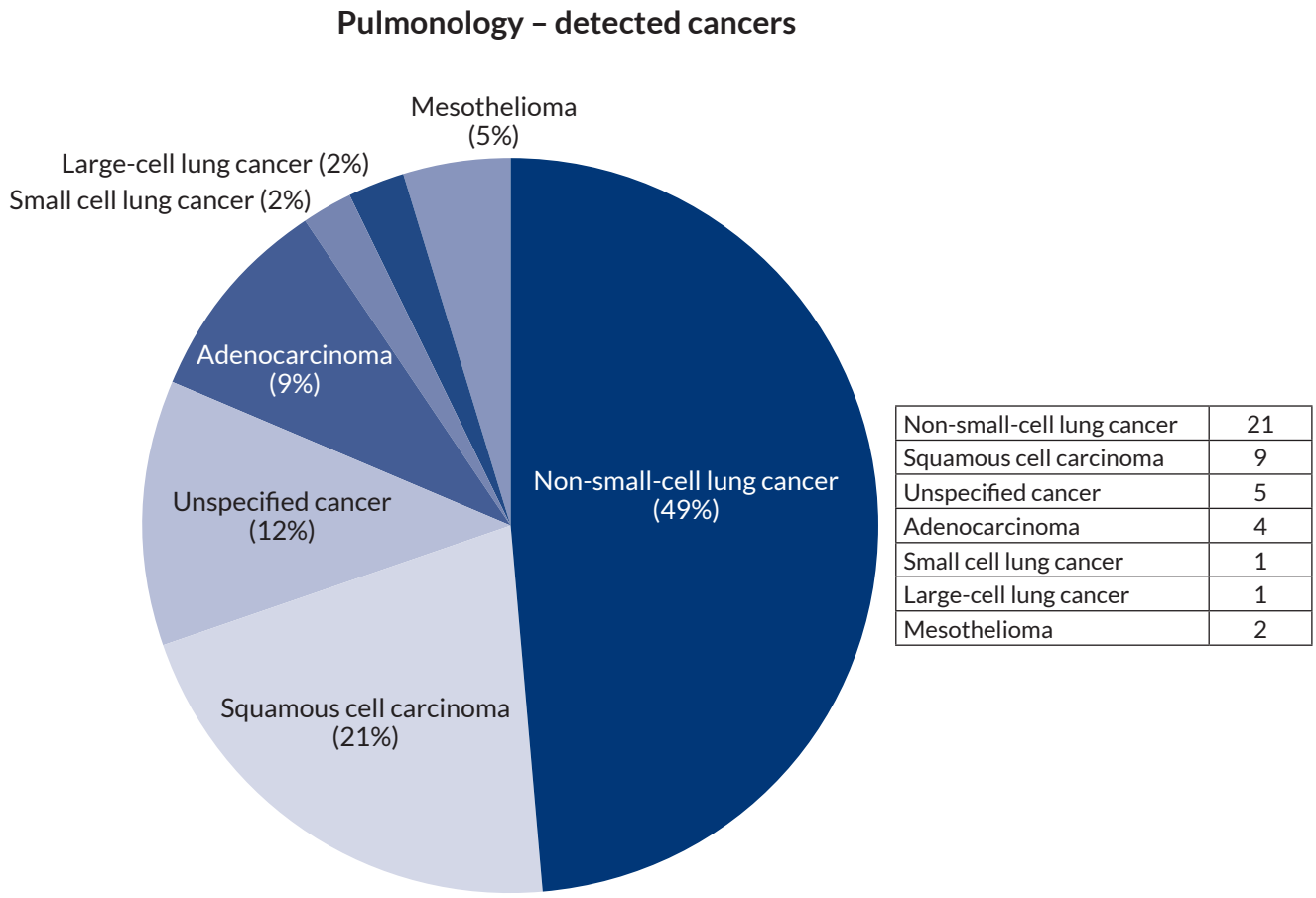
| Invasive tests at the Department of Pulmonology | LC diagnostic efficacy (%) |
|---|---|
| Bronchofiberoscopy | 35.8% |
| Lung biopsy | 39.4% |
| Pleural puncture | 8.0% |

**Table 4.** Summary of pathomorphological findings obtained at the Department of Pulmonology

| Pathomorphological evaluation | Group ($n = 74$) |
|---|---|
| Non-Small Cell Lung Cancer | 21 (28.4%) |
| Inflammation, dysplasia | 11 (14.9%) |
| Squamous cell carcinoma | 9 (12.2%) |
| Atypia/indeterminate cancer | 5 (6.8%) |
| Adenocarcinoma | 4 (5.4%) |
| *Mesothelioma* | 2 (2.7%) |
| Small cell carcinoma | 1 (1.4%) |
| Large cell carcinoma | 1 (1.4%) |
| Insufficient cytological material for pathological evaluation | 3 (4.1%) |
| No cancer cells in the collected specimen | 33 (44.6%) |

**Table 5.** Respiratory function findings in the study group

| Parameter | Group ($n = 45$) |
|---|---|
| Normal | 16 (35.6%) |
| Suspected restrictive ventilation disorder | 5 (11.1%) |
| Moderate obstruction | 9 (20.0%) |
| Suspected moderate restrictive ventilation disorder | 1 (2.2%) |
| Mild obstruction | 4 (8.9%) |




| | |
|---|---|
| Non-small-cell lung cancer | 21 |
| Squamous cell carcinoma | 9 |
| Unspecified cancer | 5 |
| Adenocarcinoma | 4 |
| Small cell lung cancer | 1 |
| Large-cell lung cancer | 1 |
| Mesothelioma | 2 |

**Figure 3.** Histological types of malignant tumors detected in pulmonological diagnosis

### Comparison of diagnostic quality in the Department of Pulmonology vs. Thoracic Surgery

In the second part of the paper, we attempted to assess the accuracy of pathomorphological diagnoses established in the Department of Pulmonology in LC patients, distinguishing 5 diagnostic categories (tab. 7).

We then correlated these categories with the final histological diagnosis obtained from either invasive diagnostic interventions or LC resection in the Department of Thoracic Surgery, distinguishing between malignant and benign masses (tab. 8).

It was found that NSCLC or SCLC were suspected in 23 patients (45.10%) during pulmonary diagnosis by means of cytological and histopathological evaluation. Tumour resections in the Department of Thoracic Surgery obtained consistent diagnoses in 21 patients (91.30%), with false positive diagnosis in 2 cases (8.7%). Pulmonary diagnosis in the "no neo cells" category was established in 20 patients (39.22%). Malignancy was detected in 10 patients in this group, while benign disease in the remaining 10 (50% each).

In the case of the "other neo" category, established during pulmonary diagnosis in the Department of Thoracic Surgery in 3 patients (5.88%), pleural mesothelioma was diagnosed in 2 cases, and no neoplasm was confirmed in one patient. The "benign" category included 3 cases (5.88%), with confirmed diagnosis in 2 cases, and malignancy ultimately diagnosed in 1 patient. Two "undiagnostic" cases (3.92%) from the Department of Thoracic Surgery were identified as PLC and a benign lesion, respectively.

**Table 6.** Results of univariate and multivariate logistic regression models

| Parameter | Univariate *(P-value)* | Multivariate *(P-value)* |
|---|---|---|
| Sex | 0.6135 | 0.8723 |
| Spirometry | 0.1115 | 0.0485 |
| Chest US | 0.3522 | 0.4756 |
| ECG | 0.2214 | 0.6947 |
| Bacteria | 0.4966 | 0.4416 |
| *Mycobacterium* | 0.9970 | 0.9972 |
| Chest X-ray | 0.2044 | 0.3642 |

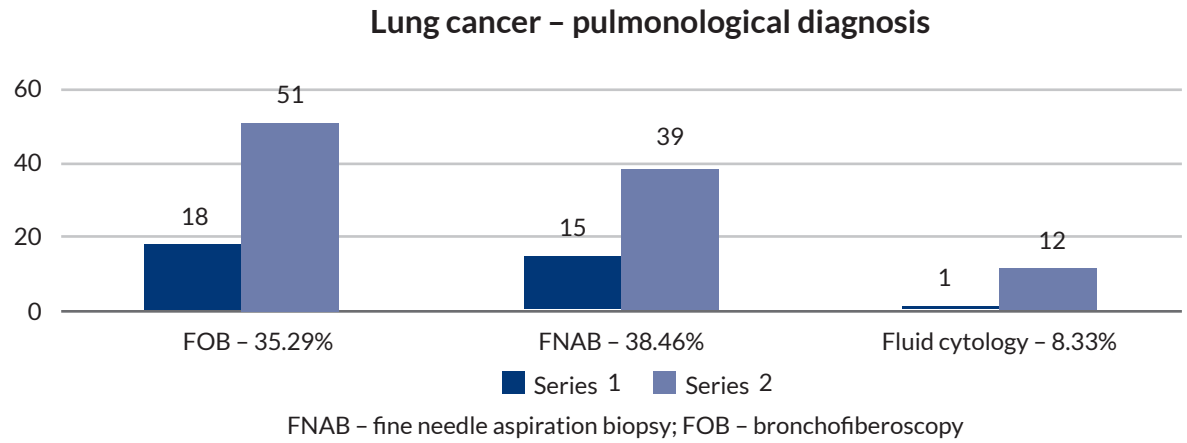



**Figure 4.** Detection of lung malignancies in invasive pulmonary investigations

In general, among 51 LC patients referred from Pulmonology to Thoracic Surgery, diagnostic concordance was obtained for 36 patients (70.59%). Statistical analysis showed a relationship close to statistical significance ($p$ = 0.0291), confirming the accuracy of pulmonological diagnosis in relation to the final diagnoses from tumour tissues after thoracic surgery. If pulmonological diagnosis raised a preliminary suspicion of malignancy, a high agreement with the final diagnosis was obtained, at the level of statistical significance ($p$ = 0.0018).

In order to determine the value of pulmonary diagnosis performed in the total study group in terms of the accuracy of detecting lung malignancies, diagnoses were classified into the following four categories: true positive (TP), true negative (TN), false positive (FP), false negative (FN).

Table 9 summarises LC diagnostic accuracy in the study group. Considering the pooled data, the following pulmonary diagnostic quality parameters for detecting lung malignancies shown in imaging were obtained:

- accuracy – 0.7059;
- positive predictive value – 0.8846;
- negative predictive value – 0.5200;
- sensitivity – 0.6571;
- specificity – 0.8125;
- informedness – 0.4696;
- markedness – 0.4046.

**Table 7.** Categories of pathomorphological LC diagnoses established in the Department of Pulmonology

| Diagnostic category | Pathomorphological microscopic description |
|---|---|
| **NSCLC/SCLC** | The specimen contained primary lung cancer cells (NSCLC or SCLC) |
| **Other cancer** | The specimen was suspected to contain cells from cancer other than PLC |
| **Benign** | The specimen was suspected to contain benign LC cells |
| **No cancer cells** | The specimen contained no cancer cells |
| **Non-diagnostic** | Non-diagnostic |
| NSCLC – non small cell lung cancer; SCLC – small cell lung cancer | |

**Table 8.** Categories of LC diagnoses after thoracic surgery verification

| Pulmonological diagnosis | Benign | Cancer | Total |
|---|---|---|---|
| **NSCLC/SCLC** | 2 | 21 | 23 |
| | 3.92% | 41.18% | 45.10% |
| **No cancer cells** | 10 | 10 | 20 |
| | 19.61% | 19.61% | 39.22% |
| **Benign** | 2 | 1 | 3 |
| | 3.92% | 1.96% | 5.88% |
| **Other type of cancer** | 1 | 2 | 3 |
| | 1.96% | 3.92% | 5.88% |
| **Non-diagnostic** | 1 | 1 | 2 |
| | 1.96% | 1.96% | 3.92% |
| **Total** | 16 | 35 | 51 |
| | 31.37% | 68.63% | 100.00% |
| NSCLC – non small cell lung cancer; SCLC – small cell lung cancer | | | |

### Evaluation of the optimality of thoracic surgery in LC patients

The type of thoracic surgical approach depended on the diagnosis, stage, and general health status of the patient. Patients underwent one of four types of thoracic surgical procedures: radical, diagnostic-radical, diagnostic, or palliative (tab. 10).

Radical surgery was performed in 24 patients (47.06%). In this subgroup, diagnostic concordance between our centres was obtained for 19 cases (79.16%). The diagnosis differed in 5 cases. However, after performing additional invasive procedures in the Department of Thoracic Surgery (bronchoscopy, pleuroscopy, mediastinoscopy), a diagnosis allowing for radical lung resection was reached. Radical diagnostic procedures, involving an intraoperative assessment of tumour tissues with simultaneous extension of the procedure to radical anatomical lung resection after detecting a tumour, were performed in 7 patients (13.7%). Pulmonological diagnosis suggested a neoplasm in all these patients; however, an intraoperative analysis of paraffin-embedded blocks was additionally needed after assessing the intraoperative image in order to perform anatomical lung resection. Another group of 13 patients (25.49%) were referred to the Department of Thoracic Surgery for diagnosis. The diagnoses were consistent in 7 (53.84%) cases, while they differed in the remaining 6 (46.15%). Ultimately, after performing invasive thoracic surgery procedures, the diagnosis was established in all patients in this group, which allowed for establishing an appropriate path of anti-cancer or pulmonary treatment. Additionally, 7 patients (13.7%) underwent palliative treatment due to advanced disease and accompanying symptoms of respiratory failure caused by pleural effusion, pneumothorax or bronchial obstruction. In this group, the diagnoses were consistent in 3 (42.86%) cases, while they differed in the remaining 4 (57.14%).

When all patients after radical and radical/diagnostic surgeries were considered, it was found that a total of 31 (60.78%) patients from the "radical" and "diagnostic>radical" groups underwent complete LC resection, with diagnostic concordance of 83.87% (26 patients). Among them, 5 (16.13%) patients underwent radical LC resection as a result of complementary invasive diagnosis at the Department of Thoracic Surgery. The cooperation between the pulmonology and thoracic surgery departments in the diagnostic process allowed for surgical procedures with an oncologically optimal extent at a level close to statistical significance ($p = 0.0437$).

It should be noted that if a malignancy was suspected during pulmonological diagnosis, this had a statistically significant impact on the selection of an optimal surgical approach ($p = 0.0029$).

### Discussion

In the contemporary literature, there are large discrepancies in the data on the incidence of malignancies among pulmonary nodules detected in imaging, which ranges from 10% to 68% [19]. In the case of screening with low-dose computer tomography (LDCT), the percentage of focal lung lesions is 19.5%, as reported by the European Respiratory Society [20, 21]. Most lung nodules are benign, but it is estimated that malignancies may account for about 20–30% of diagnosed single lung nodules [22].

Modern diagnosis should allow for more effective detection of less advanced lung malignancies, which may enable optimal surgery or other local therapeutic procedures (stereotactic radiotherapy, cyberknife, thermoablation). However, even screening with LDCT allows for detection of almost 85% of advanced LCs (stages III and IV) with high probability, but only 15% of early (stage I and II) LCs [23, 24].

The diagnostic modalities used in the Department of Pulmonology differ in their efficacy for LC. The diagnostic efficiency of FOB for endobronchial lesions is estimated at about 55–60%. However, for peripheral lesions <3 cm, this percentage is 14–50% compared to 46–80% for lesions >3 cm [25–27]. In our study group, FOB detected PLC in 35.92% patients, which was similar to the data presented by the above-cited authors.

**Table 9.** Individual Accuracy of Pulmonological Diagnosis in Detecting Lung Malignancies

| Diagnosis at the Department of Pulmonology Primary diagnosis | Diagnosis at the Department of Thoracic Surgery Department Final diagnosis | Diagnostic accuracy at the Department of Pulmonology |
|---|---|---|
| No cancer cells | Benign | TN |
| No cancer cells | Benign | TN |
| Non-diagnostic | Cancer | FN |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Benign | TN |
| No cancer cells | Benign | TN |
| No cancer cells | Cancer | FN |
| No cancer cells | Cancer | FN |
| No cancer cells | Cancer | FN |
| Non-diagnostic | Benign | TN) |

**Table 9.** Individual Accuracy of Pulmonological Diagnosis in Detecting Lung Malignancies (cont.)

| Diagnosis at the Department of Pulmonology Primary diagnosis | Diagnosis at the Department of Thoracic Surgery Department Final diagnosis | Diagnostic accuracy at the Department of Pulmonology |
|---|---|---|
| NSCLC/SCLC | Benign | FN |
| No cancer cells | Benign | TN |
| No cancer cells | Benign | TN |
| NSCLC/SCLC | Cancer | TP |
| Other cancer | Cancer | TP |
| Other cancer | Benign | FP |
| Other cancer | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Cancer | FN |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Cancer | FN |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Benign | TN |
| No cancer cells | Cancer | FN |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Benign | TN |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Cancer | FN |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Benign | TN |
| NSCLC/SCLC | Cancer | TP |
| Benign | Benign | TN |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Benign | FP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| NSCLC/SCLC | Cancer | TP |
| No cancer cells | Cancer | FN |
| No cancer cells | Cancer | FN |
| Benign | Benign | TN |
| No cancer cells | Cancer | FN |
| Benign | Cancer | FN |
| No cancer cells | Benign | TN |

NSCLC – non small cell lung cancer; SCLC – small cell lung cancer; TP – true positive; TN – true negative ; FP – false positive; FN – false negative

**Table 10.** Types of thoracic surgery by LC diagnostic concordance

| Procedure | concordance | diagnostic incompatibility | Total |
|---|---|---|---|
| **Radical** | 19 (37.25%) | 5 (9.80%) | 24 (47.06%) |
| **Diagnostic>Radical** | 7 (13.73%) | 0 (0.00%) | 7 (13.73%) |
| **Diagnostic** | 7 (13.73%) | 6 (11.76%) | 13 (25.49%) |
| **Palliative** | 3 (5.88%) | 4 (7.84%) | 7 (13.73%) |
| **Total** | 36 (70.59%) | 15 (29.41%) | 51 (100.00%) |

FNAB is one of the basic tools for the diagnosis of peripheral tumours. The diagnostic efficacy of this approach in lung cancer is estimated at 45–60% [28]. For example, Madan et al. [29] showed that percutaneous FNAB identified approximately 60% of lung nodules as malignant, 30% as inflammatory, 2.5% as granulomas, and 2.5% as suspected of malignancy. The collected material was non-diagnostic in 5% of cases. In our study, the efficacy of FNAB in the pulmonary diagnosis of malignancies was 38.46%.

It is assumed that in advanced cancers with pleural effusion, puncture with fluid cytology allows for the diagnosis of approximately 40–87% of malignant neoplasms [30,31]. In our study, the efficacy of this approach was lower, i.e. 8.33%.

In the last decade, VATS combined with lung biopsy (VATS-LB) was the gold standard in the diagnosis of LC, lymphadenopathy and pleural effusions of unknown aetiology [17]. In the period covered by the author's research, the VATS procedure was taking its first steps in thoracic surgery in our region. Hence, some invasive thoracic procedures were performed via minithoracotomy and, in advanced peripheral tumours and with pleural involvement, using pleuroscopy. It is estimated that the efficacy of lung biopsy reaches 89–95%, and that VATS-LB is characterised by a low risk of complications [32, 33]. Thoracic surgery departments have a larger and more effective arsenal of invasive tools that allow for obtaining diagnostic material from LC and regional nodal or pleural metastases. An undeniable advantage is that in the case of resectable tumours it is possible to combine the collection of a specimen or the entire tumour with an intraoperative evaluation and, if the diagnosis of NSCLC is confirmed, perform a simultaneous anatomical lung resection with regional lymphadenectomy. Marchevsky et al. [34] obtained the following intraoperative diagnostic values for LC, depending on the size of the tumour:

- for tumours <1.1 cm: sensitivity 86.9%, specificity 100%;
- for tumours 1.1–1.5 cm: sensitivity 94.1%, specificity 100%;
- for tumours >1 cm, no false positive diagnoses were found.

However, it should be noted that intraoperative investigation performed within approximately 15–20 minutes of sample collection has its limitations. For paraffin evaluation of small adenocarcinomas with a diameter of less than 3 cm, Yehi et al. [35] achieved a sensitivity of 94% and a relatively low specificity (37%).

In the study by Sileem et al. [36], diagnostic goals in the form of a preliminary preoperative diagnosis of the disease in a group of 146 patients were obtained in 60.3% of cases with FOB with a sensitivity of 45%, 100% with CT-guided FNAB, 75% with sputum cytology, and 78% of cases with EBUS-TBNA. The concordance of the preoperative diagnosis with the diagnosis after thoracic surgery was obtained in 68% of cases; the diagnoses were incorrect in 10%, and incomplete (poorly diagnostic) in 22% of cases.

It can be said that the quality of pulmonological diagnosis in our study group of 51 LC patients after thoracic surgery verification was high. Almost 70.6% of LC patients had a correct diagnosis established in the Department of Pulmonology, which enabled proper choice of further diagnostic and therapeutic strategies. Among patients who underwent optimal lung resection, 83.87% had correct diagnosis established in the Department of Pulmonology, while the remaining 16.13% had an intraoperative histopathological examination performed in the Department of Thoracic Surgery, which allowed for combining the diagnostic and therapeutic procedures.

Based on our study, it was found that cases of lung nodules in which no cancer cells were detected during pulmonary diagnosis require great clinical attention as almost 50% of cases were ultimately diagnosed with malignancy in the Department of Thoracic Surgery.

To conclude, cooperation between a pulmonologist and a thoracic surgeon may be of paramount importance for the rapid and effective identification of LC origin and successful surgical treatment of patients with early-stage disease. In the case of advanced tumours, thoracic surgical diagnosis enables much earlier implementation of systemic anti-cancer treatment.

## Conclusions

- The efficacy of invasive diagnostic procedures performed at the Department of Pulmonology for lung malignancies was estimated at 35.8% for bronchofiberoscopy and 39.4% for transthoracic lung biopsy.

- The diagnostic concordance in LC patients who were diagnosed in the Department of Pulmonology and then underwent thoracic surgeries was 70.59%.
- Collaboration of the Department of Pulmonology with complementary thoracic surgery diagnosis for LC detection allowed for optimal extent surgical treatment in 60.7% of patients, with diagnostic concordance of 83.87%.
- The diagnosis of a malignant tumour in the Department of Pulmonology allowed for an optimal thoracic surgery procedure with high statistical significance ($p = 0.0029$).
- Reduced ventilation reserves observed in spirometry in LC patients were negatively correlated with the diagnosis of lung cancer ($p = 0.0485$).

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# ANALYSIS OF THE AETIOLOGY OF ACUTE SUPPURATIVE OTITIS MEDIA IN PATIENTS TREATED BETWEEN 2023 AND 2024 AT THE MILITARY INSTITUTE OF MEDICINE – NATIONAL RESEARCH INSTITUTE, DEPARTMENT OF PAEDIATRICS, NEPHROLOGY AND PAEDIATRIC ALLERGOLOGY

## Analiza etiologii ostrych ropnych zakażeń ucha środkowego u pacjentów hospitalizowanych w Klinice Pediatrii, Nefrologii i Alergologii Dziecięcej Wojskowego Instytutu Medycznego – Państwowego Instytutu Badawczego leczonych w latach 2023–2024

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**Abstract**

**Introduction and objective:** Acute otitis media is one of the most common inflammatory conditions in childhood. The aim of the study was to analyse the aetiology of acute suppurative otitis media in paediatric patients hospitalised between 2023 and 2024. **Materials and methods:** Seven patients with acute suppurative otitis media with perforation who underwent ear canal swabbing for culture were retrospectively analysed. **Results:** The following pathogens were isolated: *Haemophilus influenzae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus pyogenes* and *Staphylococcus epidermidis*. **Conclusions:** Culture with antibiogram is crucial in cases with tympanic membrane perforation and purulent discharge for selecting a targeted and effective antibiotic therapy.

**Streszczenie**

**Wprowadzenie i cel:** Ostre zapalenie ucha środkowego jest jedną z najczęstszych chorób zapalnych wieku dziecięcego. Celem pracy była analiza etiologii ostrych ropnych zapaleń ucha środkowego z perforacją u pacjentów pediatrycznych, hospitalizowanych w latach 2023–2024. **Materiał i metody:** Analizie retrospektywnej poddano dane pacjentów hospitalizowanych z powodu ostrego ropnego zapalenia ucha środkowego z perforacją, u których wykonano wymaz z przewodu słuchowego i posiew uzyskanego materiału. **Wyniki:** U dzieci, u których wykonano posiew ropnej wydzieliny z objętego zapaleniem ucha wyizolowano następujące patogeny: *Haemophilus influenzae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Staphylococcus epidermidis*. **Wnioski:** W przypadku perforacji błony bębenkowej i wycieku ropnej wydzieliny ocena posiewu z antybiogramem jest kluczowa w doborze celowanej i skutecznej antybiotykoterapii.

**Keywords:** *Streptococcus pyogenes*; *Pseudomonas aeruginosa*; acute suppurative otitis media

**Słowa kluczowe:** *Streptococcus pyogenes*; *Pseudomonas aeruginosa*; ostre ropne zapalenie ucha środkowego

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## Introduction

Acute suppurative otitis media (ASOM) is a common childhood infection characterised by a sudden onset of symptoms and a dynamic course. The tympanic mucosa, the mastoid cavity, and the Eustachian tube may be involved. The incidence of cute otitis media (AOM) peaks in the autumn and winter. Most cases occur in children between 6 and 24 months of age [1]. About 60% of children under 4 years of age have had at least one AOM episode [2]. The infection typically spreads from the nasal cavity or nasal pharynx, through the Eustachian tube. The blood-borne route may co-occur in the course of severe infectious diseases, while the exogenous route is a direct consequence of tympanic membrane trauma.

Patients with AOM, which typically occurs as a complication of viral respiratory tract infection, usually present with bacterial and/or viral discharge in the tympanic cavity [3]. Otitis media, recurrent acute otitis media (RAOM) and chronic otitis media with effusion (COME) in particular, may affect language and cognitive development. AOM risk factors include:

- Eustachian tube dysfunction;
- recurrent upper respiratory tract infections (mainly in children attending nurseries/kindergartens);
- inhalant and food allergies;
- hypertrophied pharyngeal tonsil;
- craniofacial abnormalities;
- exposure to tobacco smoke;
- short breastfeeding (up to 3 months of age) [4, 5].

The clinical picture of AOM depends on the patient's age and is characterised by a wide spectrum of symptoms ranging from restlessness, reluctance to suck, tender tragus in infants; through rhinitis, fever, cough, vomiting in older children, including specific symptoms of ear inflammation, such as ear pain, hearing impairment or discharge in the ear canal. Symptoms of tympanic membrane (TM) perforation include an increase in pain and its resolution after the leakage of blood-stained purulent contents. In addition to the clinical picture, the diagnosis is based on otoscopic findings. The image of the tympanic membrane in AOM may vary, depending on the duration and aetiology of infection. The following 4 features of the tympanic membrane are assessed during otoscopy: position, mobility, colour and transparency. Congestion and thickening of the tympanic membrane, dilated TM vessels, impaired mobility and reduced transparency obscuring anatomical details are indicative of inflammation. TM malformation into the external auditory canal has the greatest predictive value in identifying tympanic effusion [6]. The presence of purulent discharge behind TM indicates bacterial aetiology. In 12 of the 17 guidelines reviewed, the diagnosis of AOM was based on the presence of fever and otalgia, effusion in the tympanic cavity and TM inflammation [7, 8]. About 50% of patients with AOM do not develop otalgia, and tender tragus alone does not indicate middle ear inflammation.

Management depends on the child's age and clinical symptoms. Since viruses are the main aetiology of AOM in children, symptomatic management is the treatment of choice. Ibuprofen is the preferred treatment for relieving symptoms due to its anti-inflammatory effects. It alleviates pain and fever within 24 hours in 2/3 of children with AOM. Lack of improvement after symptomatic treatment in a follow-up after 1–3 days, including increased TM congestion, persistent fever >38°C, or effusion behind TM, is an indication for antibiotic therapy. Other indications include:

- age <6 months;
- fever >39°C;
- severe earache;
- vomiting;
- children <2 years of age with bilateral or severe AOM;
- craniofacial malformations;
- autoimmune deficiencies;
- Down's syndrome;
- ear discharge,
- recurrent AOM: 3 episodes/6 months or 4 episodes/year [9].

The incidence of TM perforation is estimated at 2–10% of all diagnosed AOM cases. If AOM is accompanied by purulent discharge, an ear swab should be done before starting antibiotics. Appropriately selected antimicrobial therapy leads to discharge resolution and spontaneous closure of perforated TM. Most guidelines point to amoxicillin as first-line treatment. In the case of failure, amoxicillin with clavulanic acid or ceftriaxone is recommended [3]. Topical antibiotics are not recommended due to limited efficacy and the risk of complications in cases of membrane disruption. Topical treatment is reserved for patients with ventilation drainage, where the use of ciprofloxacin drops may be considered at an initial stage [9].

## Aim

The aim of this study was to analyse the aetiology and treatment outcomes in acute suppurative otitis media in our patients.

## Materials and methods

Medical records of patients treated for AOM with TM perforation in the Department of Paediatrics, Paediatric Nephrology and Allergology of Military Institute of Medicine – National Research Institute (WIM-PIB) in the period from 3rd May 2023 to 11th May 2024. The following data were collected: sex, age at diagnosis, clinical symptoms (fever, ear discharge, TM perforation), aetiology of infection and treatment used. Otitis was diagnosed as a red TM in otoscopy and the presence of purulent discharge. All patients had swabs taken from the external ear canal for culture. The infection status was verified in the Microbiology Laboratory of the Department of Laboratory Diagnosis (WIM-PIB). Data enabling identification of patients (name, surname, Polish Resident ID No.) were included in the analysis. The personnel of the Department of Paediatrics, Paediatric Nephrology and Allergology (WIM PIB) were the administrators of the patients' data.

## Results

Of the children diagnosed and treated for AOM with TM perforation in the Department of Paediatrics, Paediatric Nephrology and Allergology, positive culture was ob-

tained in 7 children (2 girls and 5 boys) aged between 5 weeks and 10 years. Patients' data, such as age, sex, AOM aetiology, otoscopic TM image, vaccination status, presence of fever, and antibiotic therapy used, are presented in table 1.

Four out of seven children presented with general symptoms, including fever; 6/7 patients had undergone full mandatory vaccination programme. One child was unvaccinated. The following pathogens were isolated in cultures taken from the affected ears: *Haemophilus influenzae*, *Pseudomonas aeruginosa* (2 patients), *Streptococcus pyogenes*, *Staphylococcus aureus* (2 patients). In one case, *Staphylococcus epidermidis* was cultured, which was probably due to a pre-laboratory error. Isolation by culture of the above pathogens formed the basis for targeted antibiotic therapy.

## Discussion

AOM can be either viral or bacterial. Enteroviruses, respiratory syncytial virus (RSV), influenza viruses, adenoviruses and rhinoviruses are responsible for viral AOM. Viral infection is believed to be a cofactor accelerating bacterial migration through the Eustachian tube [10, 11]. However, bacterial infections remain the predominant cause of both acute and recurrent otitis media, accounting for 80% of all diagnosed cases. According to available sources, *Streptococcus pneumoniae*, *H. influenzae* and *Moraxella catarrhalis* are the most common bacterial causes of AOM in children [12].

Immunisation against *H. influenzae* type b (Hib) and *S. pneumoniae* has significantly reduced the number of episodes of otitis media. The incidence of *S. pneumoniae* infections has decreased significantly since the introduction of the pneumococcal conjugate vaccine into the Immunisation Programme [10]. On the other hand, the number of unattended mandatory vaccinations has increased almost 2-fold during the last 5 years, from 48.6 thousand missed vaccinations in 2019 to 87.3 thousand in 2023 [11]. A variety of aetiologies of purulent ear infections in children were observed among patients hospitalised at the Department of Paediatrics (WIM-PIB). The isolated pathogens differed from the three most common ones reported in the National Antibiotic Guidelines or other sources [12]. A case of a 6-month-old girl with otitis media with perforation caused by *H. influenzae* was reported. Parental refusal of any vaccinations in the child was notable. *S. pyogenes* (Group A *Streptococcus*, GAS), a gram-positive coccus responsible for infections such as pharyngitis, scarlet fever and impetigo, but which can also cause life-threatening invasive infections defined as iGAS (isolation of GAS from a normally sterile site), was isolated in a 6-year-old boy with fever and purulent ear discharge. iGAS usually manifests in children as cellulitis, streptococcal toxic shock syndrome (STSS), necrotising fasciitis (NF) and pneumonia [13]. The increase in the incidence of iGAS infections among children under 10 years of age, observed from autumn and winter 2022, is alarming compared to previous years [14–16]. Factors responsible for the increased incidence of iGAS infections are not fully understood. One hypothesis is the presence of a large group of susceptible individuals, children in particular, as a consequence of the introduced pandemic containment measures, which reduced exposure to typical childhood infections and the resulting lack of specific immunity to GAS (the so-called 'immunity debt'). This is supported by a large increase in respiratory tract infections caused by viruses such as influenza virus and RSV during the same period [17, 18]. It has been estimated that GAS is responsible for 2–3% of paediatric AOM cases [10]. Acute mastoiditis (AM) is the most common potentially serious complication of AOM. It is usually caused by *S. pneumoniae* or GAS [19, 20]. Cases of brain abscesses developing as AOM complication caused by *S. pyogenes* have also been published [18]. *P. aeruginosa*, a relatively rare aetiology of otitis media, yet very important one due to the great dif-

**Table 1.** Summary of collected clinical data on patients with otitis media with perforation hospitalised in the Department of Pediatrics, Pediatric Nephrology and Allergology in the period from May 2023 to May 2024.

| Age | Sex | AOM aetiology | Otoscopic image | Mandatory vaccinations | Fever | Treatment used |
|---|---|---|---|---|---|---|
| 5 weeks | male | *Pseudomonas aeruginosa* | Left ear: purulent discharge in the auditory canal, TM partially visible – red, no reflex<br>Right ear: TM with red margins, purulent discharge behind the membrane | yes | – | ceftazidime |
| 6 weeks | male | *Staphylococcus aureus* MRSA+ | Left ear: purulent discharge in the auditory canal with visible TM perforation | yes | + | amikacin |
| 6 months | female | *Haemophilus influenzae* | Right ear: profuse purulent discharge in the auditory canal. TM bilaterally difficult to visualize | no | – | amoxicillin/clavulanic acid |
| 17 months | male | *Staphylococcus aureus* | Bilaterally reddened TM, no reflex | yes | + | amoxicillin |
| 6 years | male | *Streptococcus pyogenes* | Right ear – purulent discharge in the auditory canal, perforation possible | yes | + | amoxicillin/clavulanic acid |
| 8 years | male | *Staphylococcus epidemidis* | Right ear – purulent discharge in the auditory canal with TM perforation | yes | + | amikacin |
| 10 years | female | *Pseudomonas aeruginosa* | Right ear – purulent discharge in the auditory canal | yes | – | amikacin |

ficulty in treating conditions caused by this bacillus, was isolated form cultures of purulent ear contents collected from two patients [21]. Biofilms formed by *P. aeruginosa*, which are bacterial aggregates adhering to the surface of the middle ear cavity suspended in a self-generated extracellular matrix that provides a protective environment, are source of recurrent and persistent infections. Bacterial biofilms show increased resistance to antibiotics and host's protective mechanisms, giving rise to recurrent infections in closed body cavities, such as the middle ear [22, 23]. A good therapeutic response can be achieved by combining two antibiotics, e.g. ceftazidime with an aminoglycoside, obtaining a synergistic effect in an inpatient setting [24, 25]. Due to some cases of arthropathy reported after fluoroquinolones, this group of antimicrobials is reserved for life-threatening situations in children [26, 27].

*S. epidermidis* and *S. aureus* were isolated by culture in 2 described patients, and may represent bacterial flora of the external auditory canal. We would like to draw attention to the correct technique for collecting samples for examination, as an incorrectly performed procedure may prevent proper identification of the aetiological agent. The presence of infected, purulent discharge in the middle ear may cause TM perforation. This occurs as a result of chronic negative pressure in the tympanic cavity. Minor perforation usually heals within a few weeks, while larger perforations sometimes require an ENT intervention. Perforation can be diagnosed based on a leakage of purulent discharge into the ear canal, which was observed among the patients discussed in this study. Additionally, children susceptible to otitis media may present with symptoms of chronic otitis and their sequelae, including hearing impairment [28, 29]. There are clinical conditions with a much milder course, such as exacerbation of seasonal allergic rhinitis, redness of the eardrum associated with crying or trauma. Such non-purulent conditions do not pose a risk of serious infectious complications, and the use of antibiotics in their treatment may compromise the protective effect of antibiotics in AOM [30]. It may also indirectly lead to purulent otitis with a different aetiology than before. Furthermore, the number of pathogens resistant to commonly used antibiotics is growing, which is another threat to paediatric patients. Even short cycles of antibiotic therapy may be associated with the emergence of resistant pathogens [31, 32]. Identification of pathogens using specific criteria prompts therapeutic decisions and shapes trends for medical interventions. Also, attention should be paid to social and educational strategies to combat hearing loss associated with otitis media. These measures should involve the child's family, healthcare providers and be embedded in coordinated primary care systems [33].

## Conclusions

Therapeutic decisions should be made individually for each case. Careful monitoring of patients and early implementation of clinically appropriate therapy is recommended. In cases with purulent ear discharge, the decision on antibiotic treatment should be based on swab culture as targeted antimicrobial therapy will reduce the risk of severe complications such as mastoiditis or meningitis [10]. Our findings, in line with current guidelines, confirm the benefits of immunisation in preventing infections caused by pathogens such as *H. influenzae* and *S.pneumoniae*. Further research is needed to determine the cause of the growing incidence of infections with a different aetiology than generally assumed.

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# IN-HOSPITAL MANAGEMENT AND RECONSTRUCTIVE TREATMENT OF DOG BITE WOUNDS OF THE FACE REGION

## Postępowanie szpitalne oraz leczenie rekonstrukcyjne w przypadku ran kąsanych okolicy twarzy po ugryzieniu przez psa

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**Abstract**

Dog bite injuries typically require specialised treatment in a hospital setting. Bites in the facial area present a unique therapeutic challenge due to the complex nature of the injury, particularly when tissue loss is clinically evident. In the case presented, a 32-year-old patient was admitted to the plastic surgery department following a dog bite to the left cheek, upper lip, labial commissure, and vermilion on the left side. During hospitalisation, the patient received anti-tetanus prophylaxis and underwent an assessment for rabies risk, and the tissue defect was repaired using reconstructive techniques, resulting in a fully satisfactory outcome. The case illustrates one of the many techniques and approaches available for reconstructing tissue defects in the facial region. The treatment of facial injuries, particularly those involving the lips and oral mucosa, requires a multimodal approach. This includes rapid assessment of the situation, prevention of infectious disease transmission, careful selection of surgical and reconstructive techniques, and often psychological support.

**Streszczenie**

Rany kąsane twarzy spowodowane przez psy są zwykle wskazaniem do leczenia specjalistycznego w warunkach szpitalnych. Stawiają one przed lekarzami szczególne wyzwanie terapeutyczne z uwagi na wielopłaszczyznowy charakter takiego urazu, zwłaszcza gdy dochodzi do ubytku tkanek. Prezentujemy przypadek 32-letniej pacjentki, która została przyjęta na oddział chirurgii plastycznej z powodu pogryzienia przez psa lewej okolicy policzka, wargi górnej wraz z kątem ust oraz czerwieni wargowej po stronie lewej. W trakcie hospitalizacji zastosowano profilaktykę przeciwtężcową, oceniono niebezpieczeństwo transmisji wścieklizny, a następnie zaopatrzono ubytek tkanek, stosując techniki rekonstrukcyjne, uzyskując w pełni zadowalający efekt końcowy. Przedstawiony przypadek wskazuje na jedną z wielu możliwych technik w zakresie rekonstrukcji ubytków tkankowych okolicy twarzy. Leczenie urazów twarzy, zwłaszcza warg i błony śluzowej jamy ustnej, wymaga złożonego podejścia, obejmującego szybką ocenę sytuacji, zapobieganie transmisji chorób zakaźnych, odpowiedni wybór technik chirurgicznych, w tym rekonstrukcyjnych, oraz często również równolegle wsparcie psychologiczne.

**Keywords:** dog bite wound; face region; reconstructive treatment

**Słowa kluczowe:** rana kąsana po ugryzieniu przez psa; okolica twarzy; leczenie rekonstrukcyjne

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## Introduction

Dogs are among the most popular pets worldwide [1]. In 2020, nearly half of the Polish population (42%) statistically owned at least one dog [2]. Dog bite injuries to the face typically require specialised treatment in a hospital setting [3]. In Poland, an estimated 13 out of every 100,000 inhabitants experience dog bites annually. Children are more frequently bitten than adults, and men are bitten more often than women. Facial bite injuries are particularly concerning and account for a significant portion of such incidents [4]. The facial region is involved in approximately 44–70% of dog bite cases, with the mouth being among the most frequently affected areas [1, 5]. Facial injuries resulting from dog bites present unique therapeutic challenges due to the intricate anatomy of the area and the critical importance of preserving both functionality and aesthetics. Furthermore, facial bites result in not only physical trauma but also significant psychological and emotional distress [6, 7]. Studies have shown that individuals with facial deformities experience reduced life satisfaction, lower self-esteem, and an increased risk of alcohol addiction and depression [8]. Given the multidimensional and multifaceted nature of treating such injuries, particularly in young patients, careful and appropriate selection of surgical techniques, including reconstructive approaches, plays a crucial role in determining the outcomes of subsequent treatment.

## Case report

A 32-year-old female patient presented to the hospital emergency department following a dog bite. The patient reported being bitten by a neighbourhood dog which, according to the owner, had been vaccinated against rabies. Physical examination of the patient revealed tissue loss in the left cheek, upper lip, labial commissure, and vermilion on the left side (fig. 1). Before admission to the department, the patient was administered tetanus toxoid, and pain management was initiated.

Based on the clinical assessment, the patient was deemed suitable for bite wound debridement and reconstructive treatment of the soft tissue defect.

In the operating theatre, under general anaesthesia, the wound was disinfected through copious irrigation with an antiseptic solution. The tissue defect was reconstructed using local tissue reserves from the left cheek. Reconstruction of the upper lip and vermilion was performed with the inverted flap technique, using a flap from the inner cheek, to restore the continuity of the orbicularis oris muscle (fig. 2 and fig. 3).

The following day, after a scheduled dressing change and confirmation of normal wound healing, the patient was discharged from the hospital with instructions to change the dressings independently and to continue empirical oral antibiotic therapy with clindamycin 600 mg three times a day. The patient returned for a local follow-up approximately 60 days post-procedure. She did not report any symptoms indicative of complications from the injury. Satisfactory wound healing was achieved, and no significant deficits in facial expression were observed. Only a residual limitation in the maximum opening of the

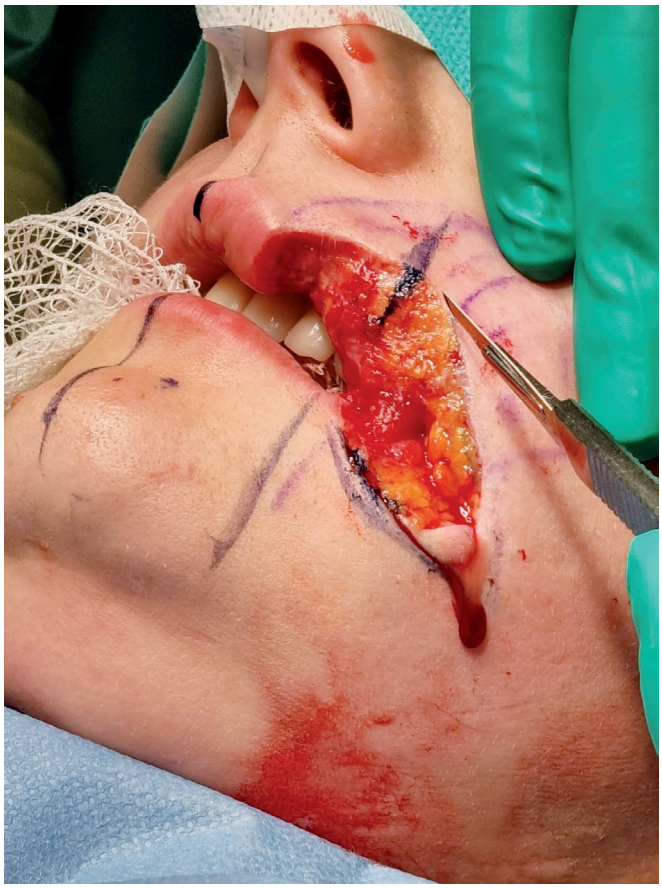

**Figure 1.** Visible tissue loss in the left cheek area, upper lip (including the labial commissure), and vermilion on the left side

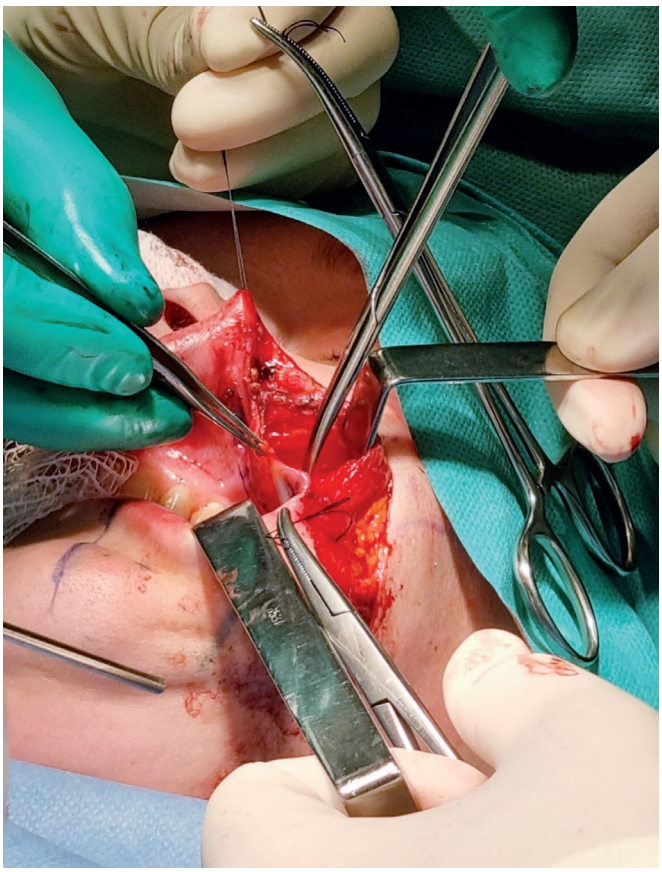

**Figure 2.** Intraoperative view during mucosal flap creation

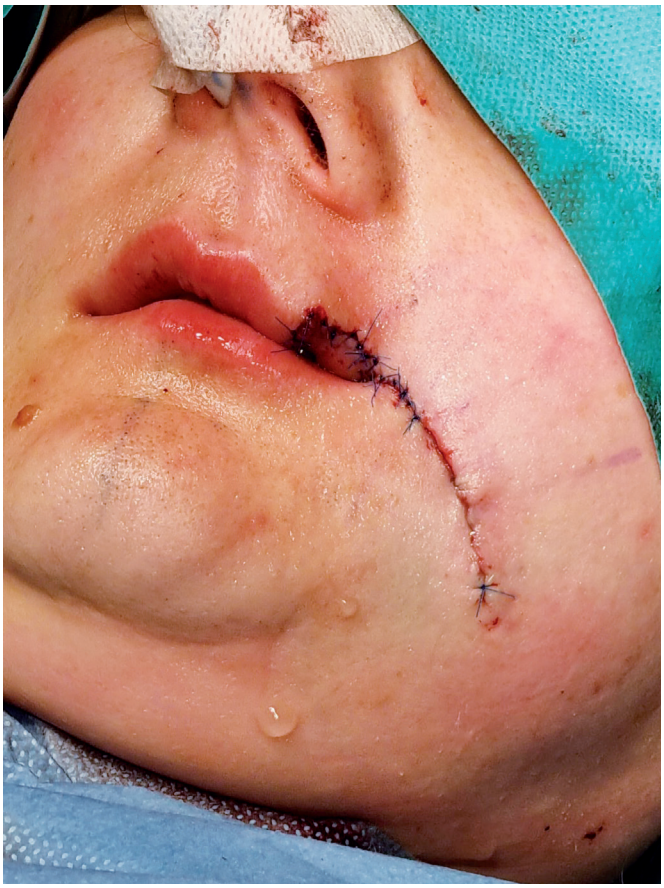

**Figure 3.** Appearance of the lacerated wound following reconstructive management

mouth corner on the operated side was observed compared to the healthy side (fig. 4 and fig. 5).

## Discussion

Approximately half of all individuals will experience an animal bite at some point in their lifetime. In 90% of cases, animal bites are inflicted by pets [9]. Given the high prevalence of animal bites, prompt and appropriate diagnostic and therapeutic interventions are essential. Treatment involves prompt and thorough wound irrigation, evaluating the need for post-exposure measures to prevent rabies and tetanus transmission, mechanical debridement, and assessing the feasibility of primary closure through simple suturing or reconstructive surgical techniques [10]. Most studies also highlight the significance of prophylactic antibiotic therapy in managing facial injuries resulting from dog bites [11]. In our patient, empirical treatment with clindamycin 600 mg three times daily was initiated. Importantly, inadequate or delayed intervention following a dog bite can result in complications documented in the literature, such as local wound infections, brain abscesses, hypertrophic scars, scar contractures, or infections like rabies and tetanus [12–14].

Despite appropriate management and the expertise of medical personnel, the extent of facial trauma often prevents simple wound closure and necessitates the use of advanced reconstructive techniques, either during the initial surgery or as part of secondary repair procedures in cases of complications or failures [15, 16]. Reconstruction of the cheek, vermilion, and oral mucosa must take into account the complex anatomy and the primary functions these structures serve, such as speech, facial expression, and food intake [17].

There are numerous techniques and approaches available for reconstructing tissue defects in this area of the face [18–20]. Local flaps are frequently the preferred option for facial reconstruction due to their uniform skin colour and tissue structure, which are essential for achieving optimal aesthetic outcomes. Rotation flaps, offset either anteriorly or laterally, are effective for repairing defects by providing adequate tissue with a reliable blood supply. They are particularly useful for smaller, localised defects within a single anatomical area [21].

In vermilion reconstruction, the choice of surgical technique primarily depends on the depth of the injury. For less extensive and shallow injuries, local flaps, particularly mucosal flaps, are typically used, as demonstrated in the reported case. For larger defects that extend beyond one-third of the lower lip or one-fourth of the upper lip,

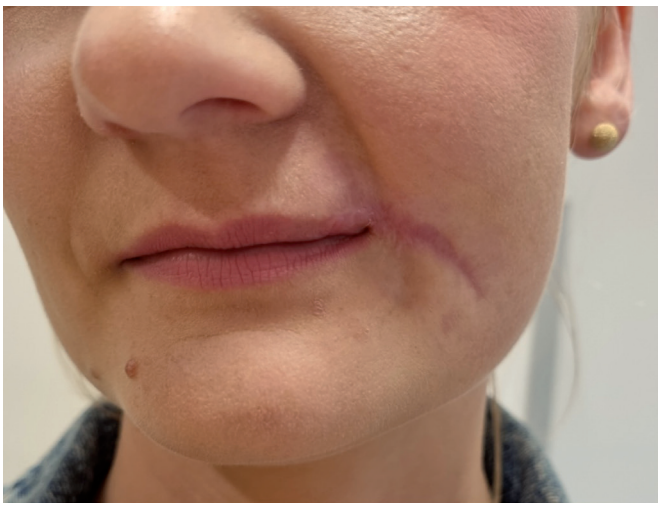

**Figure 4.** Follow-up of healing and appearance of the scar approximately two months post-surgery

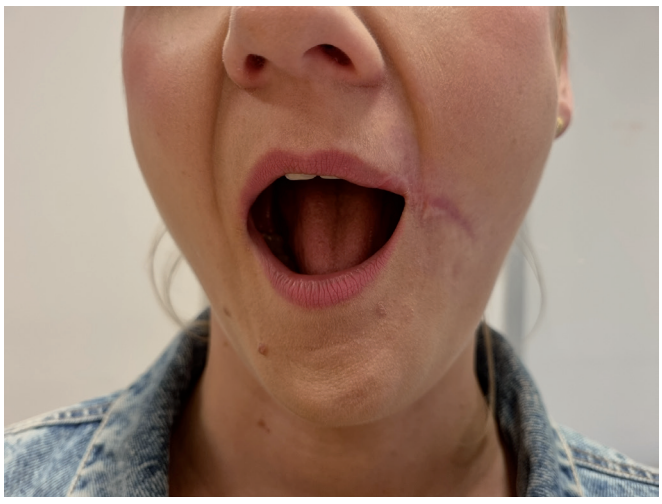

**Figure 5.** Dynamic (functional) effect two months post-surgery

including those involving full-thickness loss of the vermilion, reconstructive procedures can be categorised into three groups. One comprises the Abbé-Estlander flap surgery, i.e. a cross-lip procedure involving rotation flaps using tissues from the lower lip. A disadvantage of this method is the motor denervation of the created flaps. Another group of techniques uses fan-shaped flaps rotated around the angle of the mouth, such as the Karapandzic method, in which symmetrically created flaps maintain both motor and sensory innervation. Finally, it is worth mentioning the option of buccal flaps, as described in the Bernard-Burrow lip reconstruction technique modified by Webster, which involves preparing buccal flaps and positioning them medially to the defect area [22, 23].

Standard treatment for patients following dog bites also involves prophylaxis for tetanus and rabies. The approach to preventing tetanus transmission varies based on the patient's current vaccination status, the animal involved, and an assessment of the risk of transmission, which includes evaluating the macroscopic appearance of the wound. Management involves passive immunisation (administering tetanus immunoglobulin) and/or active immunisation (administering a vaccine) [24]. In the reported case, the patient received one dose of tetanus antitoxin following an evaluation by the emergency department team.

If a patient is bitten by an animal with an unknown or questionable vaccination status, they should be promptly referred to an infectious diseases outpatient clinic for a thorough assessment of the need for further post-exposure treatment. Post-exposure procedures can be delayed until rabies is confirmed in the animal if it showed no symptoms of the disease at the time of exposure. In such cases, a 15-day veterinary observation is conducted (this applies only to pets) [25]. In the described case, following the observation of the dog and confirmation of its rabies vaccination, no further measures were deemed necessary.

## Conclusions

Management of facial trauma resulting from a dog bite always requires an individualised approach. The choice of therapy depends on the severity of the injury, the patient's overall health and vaccination status, as well as the desired aesthetic outcomes. The primary goal is to restore both the function and appearance of the damaged tissues, thereby enhancing the patient's overall quality of life.

## Conclusions

Dog bites are relatively common and present a considerable therapeutic challenge. Treatment of facial injuries, particularly those involving the lips and oral mucosa following a bite, requires a comprehensive approach. This includes prompt assessment, prevention of infectious disease transmission, appropriate selection of surgical techniques (including reconstructive procedures), and often additional psychological support. The reported case illustrates a comprehensive approach to treating a dog bite injury in a young adult woman, emphasising the complexity of the condition and the challenges associated with in-hospital management and surgical reconstruction of post-traumatic tissue defects.

*The patient provided consent for the publication of photographs.*

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# LEFT VENTRICULAR THROMBUS – DIAGNOSIS AND MANAGEMENT BASED ON A CASE REPORT

## Skrzeplina w lewej komorze serca – diagnostyka i postępowanie na podstawie opisu przypadku

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**Abstract**

Left ventricular thrombus is one of the complications of ST-elevation myocardial infarction. Its presence is associated with the risk of serious embolic complications; therefore, diagnosis and effective treatment of formed thrombi are necessary. Suggested treatment methods include anticoagulation, thrombolysis and surgery, but there is no consensus on the choice of treatment method. We present a case report of a 52-year-old patient diagnosed with post-infarction left ventricular thrombus complicated by an embolic event. Due to the ineffective anticoagulant therapy, the patient underwent surgical removal of the thrombus, which resulted in its complete elimination from the left ventricle.

**Streszczenie**

Skrzeplina w lewej komorze serca jest jednym z powikłań zawału mięśnia sercowego z uniesieniem odcinka ST. Jej obecność niesie za sobą ryzyko poważnych powikłań zatorowych, dlatego konieczna jest diagnostyka i skuteczne leczenie uformowanych skrzeplin. Sugerowane metody postępowania obejmują leczenie przeciwkrzepliwe, trombolityczne i chirurgiczne, nie osiągnięto jednak konsensusu co do wyboru sposobu leczenia. Poniżej przedstawiono opis przypadku 52-letniego pacjenta, u którego rozpoznano pozawałową skrzeplinę lewej komory serca powikłaną incydentem zatorowym. W związku z brakiem skuteczności leczenia przeciwkrzepliwego u pacjenta wykonano operacyjne usunięcie skrzepliny, które pozwoliło na całkowite jej wyeliminowanie z lewej komory serca.

**Keywords:** left ventricular thrombus; embolic complications; coronary artery disease; myocardial infarction; anticoagulant therapy

**Słowa kluczowe:** skrzeplina w lewej komorze serca; powikłania zatorowe; choroba niedokrwienna serca; zawał serca; leczenie przeciwkrzepliwe

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### Introduction

Left ventricular thrombus (LVT) may develop as a complication of ongoing or past ST-segment elevation myocardial infarction (STEMI). The incidence of LVT is estimated at 4% in patients with STEMI, and about 10% in the subgroup of patients with anterior STEMI [1, 2]. The presence of a thrombus is associated with the risk of embolic complications, including ischaemic stroke or systemic embolism [3, 4]. We describe a case of a patient with LVT complicated by embolism of one of the renal segmental arteries with partial infarction of the kidney and infarction of the spleen.

### Case report

A 52-year-old patient with a history of myocardial infarction (MI) managed with angioplasty of the anterior descending coronary artery (ADCA) 15 years earlier, hypertension (HT) (not treated with antihypertensives), gastric and duodenal ulcers, active smoking, and depressive disorders, reported to the hospital

emergency department due to a 30-minute episode of burning chest pain that had occurred the day before admission, followed by severe pain in the left lower abdomen. Physical examination showed mild tenderness in the left iliac fossa on deep palpation. Ultrasonography (US) and X-ray of the abdominal cavity showed no significant abnormalities. However, due to the episode of chest pain and elevated markers of myocardial necrosis (elevated high-sensitivity troponin T: 986 ng/L vs. normal up to 14 ng/L), the patient was transferred to the cardiac intensive care unit (CICU) with suspicion of acute coronary syndrome.

On admission, he was in a good general condition, with good circulatory and respiratory function, full verbal and logical contact. He reported constant pain in the lower abdomen. Electrocardiogram (ECG) showed a regular sinus rhythm of 85/min, normal cardiac axis, QS complexes in leads V1–V3, and negative T waves in leads V4–V5 (stable in subsequent recordings). Laboratory findings included elevated markers of myocardial necrosis, normal amylase and lipase activity, and no elevated inflammatory parameters. General urinalysis revealed mild proteinuria. Transthoracic echocardiography (TTE) showed enlarged LV and left atrium, segmental contractility disorders: akinesia of the apex, apical segments of all walls and the middle segment of the interventricular septum, globally impaired left ventricular ejection fraction (LV-EF) of 35%; no significant valvular defects, signs of right ventricular overload or pericardial effusion were found. A mobile structure measuring 21 × 21 mm was identified in the apical LV region. A thrombus was suspected. Due to severe pain, elevated D-dimers and the identified structure in the left ventricle, an angio-CT scan of the abdominal aorta was performed for embolic complications, revealing absence of contrast enhancement of approximately 21 mm in the LV, which could correspond to a hypodense thrombus. Additionally, thrombosis of one of the left renal segmental arteries with middle and inferior renal infarction was detected. An isolated, conical area of right renal infarction could not be excluded. Also, an infarct zone was evident in the abdominal part of the spleen. The patient was consulted by a vascular surgeon, who concluded that revascularisation of the left kidney was not possible as the symptoms persisted for over 12 hours. A continuous unfractionated heparin (UFH) infusion was started, monitored by the activated partial thromboplastin time (APTT). The patient was also put on dual antiplatelet therapy (acetylsalicylic acid [ASA] plus clopidogrel), a proton pump inhibitor, a statin, antihypertensives and analgesics.

A follow-up echocardiography (ECHO) 7 days post admission showed no reduction in the size of the structure in the left ventricle (29 × 22 mm) despite continued anticoagulant therapy. A decision was made to perform a cardiovascular magnetic resonance (CMR) imaging to differentiate the lesion from a myxoma. The CMR revealed an akinetic aneurysm involving the mid-segment of the anteroseptal wall, apical segments of the anterior and lateral walls, the interventricular septum, as well as the apex. Additionally, there was a global reduction in left ventricular systolic function with LVEF of 36%. Cine images (a type of MRI sequence acquired to capture motion) showed a spherical hypointense structure near the LV apex. Early gadolinium enhancement (EGE) imaging showed an 18 × 12 mm hypointense structure, suggesting absence of contrast uptake, which is typical of a thrombus (fig. 1).

Late gadolinium enhancement (LGE) sequences revealed areas of subendocardial necrosis involving <50% of the myocardial thickness in the mid-inferoseptal wall segment, >50% of the myocardial thickness in the mid-anteroseptal wall segment, and nearly full-thickness necrosis in the apical segments of the anterior and lateral walls, the interventricular septum, and the apex, as well as a small, punctate area of full-thickness necrosis at the border of the basal segments of the inferior and inferolateral walls (fig. 2).

The examination showed ischemic necrosis with lack of viability in the region supplied by ADCA. During hospital stay, coronary angiography was also performed, showing 60% ADCA stenosis, and only mural lesions in the remaining coronary arteries.

Due to the presence of an LV apical thrombus complicated by an embolic event and not responding to anticoagulant therapy, the patient was qualified for surgical retrieval of the thrombus. Furthermore, the 60%

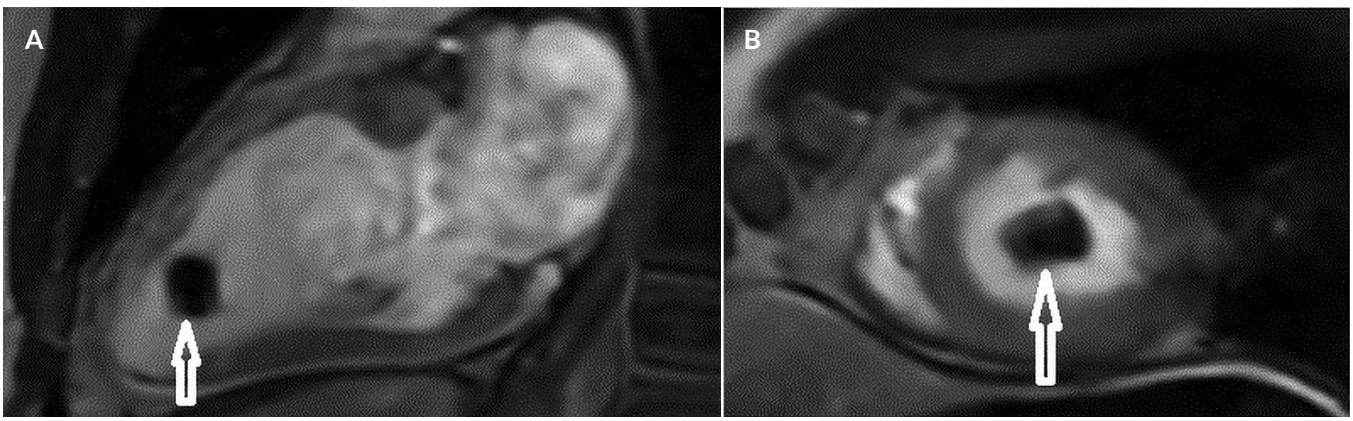


**Figure 1.** Early-enhancement sequences, **A.** dual chamber view, **B.** short axis view at the level of apical segments. White arrows indicate a hypodense thrombus

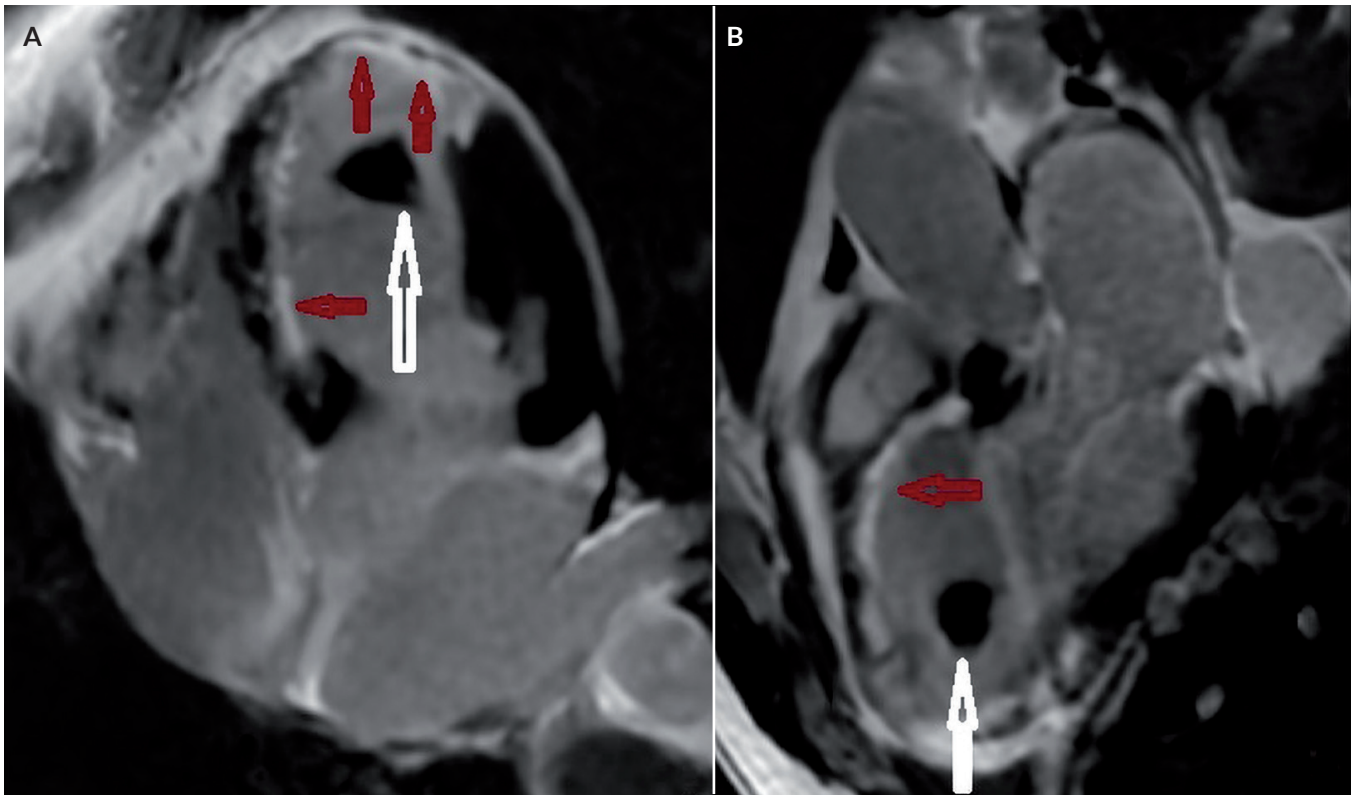


**Figure 2.** Early-enhancement sequences, **A.** four-chamber view, **B.** three-chamber view. White arrows indicate an LV thrombus, red arrows indicate examples of ischemic necrosis

ADCA stenosis identified in coronary angiography prompted a decision to perform a simultaneous coronary artery bypass grafting (CABG). The procedure was performed through sternotomy, using extracorporeal circulation. The LVT was retrieved through the left atrium accessed via the right atrium and interatrial septum, and the obtained specimen was sent for histopathological examination. This was followed by aortocoronary bypass grafting between the left internal mammary artery and ADCA. Histopathology confirmed the diagnosis of an organised thrombus, and the postoperative follow-up ECHO confirmed its total removal from the left ventricle.

## Discussion

Risk factors for post-MI LV thrombus include, among others, anterior MI, impaired LV contractility and low LVEF (especially <35%), LV aneurysm, and apical akinesia [1, 3, 5]. The presence of thrombus is associated with the risk of embolic complications, which is particularly high if the blood clot is large, balloting and mobile [2, 6–8]. The significantly increased risk of a serious complication in the form of systemic embolism manifested by ischemic stroke, ischemia of organs or limbs, and even sudden death, prompts careful monitoring of patients for thrombus formation. TTE and CMR are used for this purpose. Studies comparing these two imaging tools have reported that compared to CMR, TTE shows 21–24% sensitivity, 95–98% specificity, as well as that CMR has a lower intra- and interobserver variability in thrombus detection than TTE [9]. Although these findings support the superiority of CMR over TTE in the diagnosis of LVT, ECHO is much more available in everyday clinical practice. Therefore, it seems that MRI is more appropriate in situations when TTE raises the suspicion of a thrombus, but is not fully diagnostic or leaves doubts [2]. CMR can also be used to differentiate a thrombus from a neoplastic lesion [10, 11]. Unlike tumours, thrombi are avascular and therefore characterised by a lack of enhancement in first-pass perfusion CMR imaging, and a hypointense signal in EGE sequences, which persists in LGE sequences.

Treatment options for LVT include anticoagulation, thrombolytic therapy, and surgical retrieval. However, there is no consensus on the most optimal approach or choice of treatment method [7, 8]. Current anticoagulation guidelines suggest the use of vitamin K antagonists (VKAs) for 3–6 months with a target international normalised ratio (INR) between 2 and 3 [2, 12, 13]. The length of therapy should also be individualised due to the risk of bleeding. Currently, attempts are being made to replace VKAs with novel oral anticoagulants (NOAC). No need to monitor the anticoagulant effect with frequent INR measurements, which significantly improves the quality of life of patients, is one of their benefits. According to the available data, it is justified to use NOACs instead of VKAs, as they offer a similar therapeutic effect and are equally safe [2, 12–14]. They are particularly beneficial in patients in whom the therapeutic level of INR cannot be achieved or frequent INR measurements are a significant burden. In both cases, ECHO should be used to assess treatment efficacy.

Cases described by Agarwal et al. and Liao et al. are examples of effective use of anticoagulation therapy [15, 16]. Agarwal et al. described a case of a patient with a history of coronary artery disease (CAD), status post stenting of the anterior descending and circumflex arteries, who presented to hospital with a suspicion of MI [15]. Coronary angiography revealed three-vessel disease and the patient was referred for CABG. Preoperative TTE showed an apical LVT and an LV aneurysm. The patient was started on a continuous UFH infusion and ASA. CABG was then performed. Postoperatively, the patient complained of severe pain in the right leg, accompanied by pallor and absent pulse in both lower limbs. CT of the abdomen and lower limbs showed a large thrombus in the aortic bifurcation, occluding the right common iliac artery and nearly occluding the left common iliac artery, as well as a thrombus in the right popliteal artery. The presence of embolic material was considered a complication of the LV thrombus. The patient underwent thrombectomy with postoperative UFH, clopidogrel, followed by warfarin. Another TTE showed a decrease in the size of LVT. No new embolic complications were observed during hospital stay, and the patient was discharged home with a recommendation to continue warfarin, clopidogrel, and ASA.

Anticoagulant therapy was also effective in the case of a 37-year-old woman with a history of long-term oral contraceptives, silent MI and anteroseptal hypokinesia, as well as an LV thrombus, bilateral renal infarction and occlusion of both popliteal arteries, described by Liao et al. [16]. The implemented anticoagulant and antiplatelet therapy (ASA, clopidogrel, intravenous heparin later switched to oral warfarin) resulted in complete thrombus dissolution, as confirmed during a follow-up after 2 months of treatment.

However, anticoagulant therapy not always leads to thrombus reduction or dissolution. This was the case described by Wejner-Mik et al., where a 5-day heparin infusion failed to reduce the size of a ventricular thrombus [17]. This can be partly explained by the relatively short treatment duration.

Fibrinolytic therapy seems to be an alternative to anticoagulant therapy, although there is insufficient evidence for its efficacy and safety [2, 18]. For this reason, it is not recommended as a first-line treatment.

A clot can also be retrieved surgically. However, such interventions are associated with a high risk of death and should therefore be reserved for special cases. Due to the high risk of systemic embolic complications, surgery seems to be beneficial in cases of a large, mobile, balloting LVT, as well as if anticoagulation is ineffective or not tolerated by the patient [2, 6, 7, 13]. Surgical thrombectomy can be performed via the left ventricular apex, left atrium or aorta when a concomitant aortic valve replacement is performed [7]. Thrombectomy via the LV apex was successfully performed by, among others, Pasli et al. and Wejner-Mik et al. [7, 17]. Pasli et al. described a 74-year-old female with a significantly reduced LVEF of 10–15% with an akinetic apex and a massive thrombus adjacent to the LV apex and interventricular septum complicated by acute ischemia of both lower limbs [7]. Due to her serious condition, the mobility of the thrombus and the need to prevent further embolic complications, a decision was made to perform surgical resection. The procedure was performed through a median sternotomy, with extracorporeal circulation and an incision of the LV apex. The thrombus was retrieved, and then the ventricle was cleaned and washed out. Postoperative ECHO confirmed that the left ventricle was completely free of thrombus. A similar solution was employed by Wejner-Mik et al. in a 65-year-old patient with extensive myocardial contractility disorders and apical akinetic aneurysm, as well as a large LV thrombus complicated by right common iliac artery embolism [17]. Initially, the patient was given a continuous UFH infusion, which did not bring any improvement in the form of reduced size of the thrombus after 5 days of treatment. It was considered that prolonging anticoagulation would probably prove ineffective and involve the risk of haemorrhagic complications. Additionally, given the high risk of embolic complications associated with the presence of thrombus, it was decided to retrieve it surgically. The procedure was performed by an incision of the aneurysmal LV apex. The thrombus was completely retrieved, and the aneurysm was managed with plasty according to Dora during LV wall closure. Successful removal of the thrombus from the left atrial access was reported by Tanaka et al. [8]. They described a case of a 37-year-old woman with a history of postpartum cardiomyopathy and multiple pulmonary embolism. Echocardiography revealed a deterioration of LV systolic function with LVEF of 10% and a large, mobile LV thrombus. Considering the size, thin pedicle of the thrombus and high embolic risk, it was decided that urgent surgical intervention was necessary. An incision of the left atrium was performed, and then the thrombus was exposed and retrieved through the open mitral valve. Postoperative echocardiography revealed a small, residual mural thrombus and an increase in LVEF of up to 40%. The patient was prescribed warfarin and no recurrence of embolic complications was observed during further follow-up. The authors of the paper pointed to the benefits of the transatrial approach. Atriotomy causes no damage to the LV wall resulting in deteriorated systolic function, which is often already significantly reduced in patients with a thrombus, or to the apex of the heart, making room for future implantation of an LV assist device. Additionally, such access allows for the removal of a larger thrombus than from the aortic access during simultaneous aortic valve surgery. However, less freedom of maneuver and limited possibilities of retrieving attached or thickly pedicled thrombi is a disadvantage compared to ventriculotomy. Transaortic access is rarely chosen, but its successful use has been described by Williamson et al., who found a large, mobile thrombus in the LV apex during transoesophageal echocardiography performed during aortic valve replacement [19]. After removal of the calcified valve, the thrombus was retrieved using forceps under video guidance. Postoperative follow-up showed no thrombus, and no new clots were detected during follow-up care.

To summarise, our patient had an LV thrombus detected in TTE, and later confirmed by CMR. The thrombus was complicated by occlusion of smaller arteries supplying the left kidney and the spleen. Anticoagulant treatment with UFH was initiated, which did not bring any improvement after 7 days of therapy. Due to the previous embolic events and the risk of their recurrence, it was decided that surgical approach was necessary. The clot was retrieved through the left atrium from the right atrial and interatrial septal access, achieving complete elimination of the thrombus with no recurrence in the postoperative follow-up.

## Conclusions

The described case highlights the need to monitor patients after myocardial infarction due to the risk of a serious complication in the form of left ventricular thrombus. Patients suspected of MI complications should be regularly screened using TTE to detect abnormalities at an early stage, e.g. a forming thrombus, and receive treatment promptly enough to prevent serious embolic complications. Anticoagulants and surgical resection can be used for an organised thrombus. The choice of treatment approach should be adjusted to the patient's health status and based on the embolic–haemorrhagic balance, and the therapeutic decision should be made in consultation with the so-called heart team.

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# THE USE OF THE *LATISSIMUS DORSI* MUSCLE FLAP IN BREAST RECONSTRUCTION AFTER MASTECTOMY COMPLICATED BY IMPLANT SITE INFECTION

## Zastosowanie płata z mięśnia najszerszego grzbietu w rekonstrukcji piersi po mastektomii powikłanej zakażeniem loży implantu

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**Abstract**

The *latissimus dorsi* musculocutaneous flap has recently been increasingly used in breast reconstruction after mastectomy. The technique utilises the latissimus dorsi muscle with an island skin flap and adipose tissue to create full-thickness tissue coverage and achieve increased volume for the reconstructed breast. By combining this method with prosthetic devices, such as implants or tissue expanders, satisfactory outcomes can be achieved. This paper presents a literature review on the transplantation of the *latissimus dorsi* musculocutaneous flap and describes a case of a 43-year-old patient who underwent reconstruction using a l*atissimus dorsi* muscle flap after previous cancer treatment. The patient had previously undergone mastectomy with simultaneous breast reconstruction using implants. The procedure was complicated by implant site infection, necessitating implant removal. Breast reconstruction using the *latissimus dorsi* flap was combined with a tissue expander for subsequent replacement with an implant. The presented case suggests that the *latissimus dorsi* flap can be an effective and safe method of breast reconstruction after mastectomy in situations where less advanced reconstruction techniques fail.

**Streszczenie**

W ostatnich czasach płat mięśniowo-skórny mięśnia najszerszego grzbietu jest coraz częściej stosowany w rekonstrukcji piersi po mastektomii. Technika ma na celu wykorzystanie uszypułowanego mięśnia *latissimus dorsi* z wyspą skórną i tkanką tłuszczową w celu wytworzenia pełnowartościowego pokrycia tkankowego oraz uzyskania zwiększonej objętości rekonstruowanej piersi. Łącząc tę metodę z zastosowaniem urządzeń protetycznych, takich jak implanty lub ekspander tkankowy, można osiągnąć zadowalający efekt. W pracy przedstawiono przegląd literatury dotyczący przeszczepu płata mięśniowo-skórnego mięśnia najszerszego grzbietu oraz opis przypadku 43-letniej pacjentki, która została poddana rekonstrukcji z wykorzystaniem płata z mięśnia *latissimus dorsi* po przebytej chorobie nowotworowej. Pacjentka w przeszłości przeszła mastektomię z jednoczasową rekonstrukcją piersi z użyciem implantów. Zabieg został powikłany zakażeniem loży implantu, w efekcie czego konieczne było jego usunięcie. Rekonstrukcję piersi z użyciem płata latissimus dorsi zastosowano w połączeniu z ekspanderem tkankowym w celu późniejszej zamiany na implant. Prezentowany przypadek wskazuje, że płat *latissimus dorsi* może być skutecznym i bezpiecznym sposobem rekonstrukcji piersi po mastektomii, kiedy mniej zaawansowane techniki rekonstrukcyjne zawiodą.

**Keywords:** infection; breast reconstruction; flap plasty; latissimus dorsi muscle

**Słowa kluczowe:** zakażenie; rekonstrukcja piersi; plastyka płatowa; mięsień najszerszy grzbietu

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## Introduction

Implant site infection following breast reconstruction after mastectomy is a common complication. Breast reconstruction after mastectomy is currently the gold standard and an integral part of the treatment process. There are many reconstruction approaches, including prosthetic reconstruction (implant), a tissue expander combined with a prosthesis, or the use of patient's own tissue (mucocutaneous/adipose tissue flaps) [1].

Haematoma, infection, skin necrosis and implant loss are the most common complications encountered in medical practice following radiotherapy in patients after breast reconstruction. According to the available data, the reconstruction failure rate after radiotherapy is 6–62.6% [2]. Radiotherapy increases the risk of complications to 55% [3] and the risk of implant loss to 4.8%–33% [4].

The use of muscle flaps allows for covering deep and extensive tissue defects (post-resection or post-traumatic). Muscle is an optimally vascularised tissue material, which is used for defects after infection or irradiation, where the quality of tissue blood supply is questionable. It is commonly employed in reconstructive surgery also due to its structure. It is large, flat, and has a large flap pedicle with vessels.

## Case report

A 43-year-old woman was electively admitted to the Department of Plastic and Reconstructive Surgery and Burn Treatment due to loss of tissue in the right breast as a result of postoperative wound dehiscence following the removal of a tissue expander due to infection. She had a history of right mastectomy with simultaneous breast reconstruction using an implant, with adjuvant radiotherapy. The patient was qualified for right breast reconstruction with a latissimus dorsi flap (LD flap), with simultaneous placement of a temporary tissue expander and elective breast augmentation. The procedure began with a skin incision in the shape of the future LD island flap, and a simultaneous resection of a fragment of skin with the tissue defect. While dissecting the tissues, the capsule surrounding the old implant was accessed. The implant site was rinsed with an antiseptic. The capsule was incised longitudinally from the inside at the greatest adhesions and tensions in order to create space for the expander. Then a tunnel was made in the subcutaneous tissue towards the axilla, through which the prepared LD flap was to pass. Using a separate access on the back, an incision was made in the skin and the subcutaneous tissue, reaching the latissimus dorsi muscle. A flap of the appropriate size was raised to cover the tissue defect. The released island myocutaneous flap was transferred through the previously created subcutaneous tunnel to its target site on the right breast to maintain proper blood supply of the island. The patient was positioned on her left side during this part of intervention. Using subcutaneous and cutaneous sutures, the LD flap was attached to the right breast acceptor site. The patient was then placed on her back to proceed to the next stage of the procedure.

The tissue elasticity of the site was adjusted to the expander. Under sterile conditions, a Mentor 400cc expander was introduced under the created flap. Drains were placed and a port for fluid administration was introduced in order to gradually fill the expander, which was filled with 20 $cm^3$ and then checked for potential leaks and the correct level of filling. Non-absorbable sutures were placed to recreate the inframammary fold and provide tissue support for the lower pole of the expander.

In the days following the procedure, the wound healed normally, without any inflammatory reaction around the sutures. The blood supply to the island was satisfactory. Follow-up visits were planned according to the schedule. The patient was discharged home in a good general and local condition. The peri- and intraoperative course was uneventful. There was no increase in body temperature or wound healing disorders. There was no visible inflammatory reaction around the sutures. The blood supply to the skin island remained normal during follow-up visits. On postoperative day 4 of hospital stay, follow-up laboratory tests were performed, which did not deviate from the norm. A slight increase in CRP to 2.3 mg/dL (norm up to 0.5 mg/dL) and a decrease in RBC to 3.60 × 1012/L (norm: 3.81–5.13) were observed. Electrolyte levels were as follows: $Na^+$: 135 mmol/L (norm: 136–145), $K^-$: 5.1 mmol/L (norm: 3.5–5.1). Renal parameters were normal.

Amoxicillin was used for 7 postoperative days as perioperative prophylaxis.

Follow-up visits were held on day 1 after the procedure, and then every other day until discharge. Redon drains were removed 6 days post surgery due to the lack of abnormalities in their contents. It was decided to discharge the patient home on postoperative day 6.

The patient was instructed to maintain a resting lifestyle for the first 14–21 days after surgery. Then, gradual physical rehabilitation was prescribed (return to full life activity after 6–8 weeks). A high-protein diet was recommended to ensure optimal conditions for postoperative wound healing. Outpatient follow-up visits were arranged to assess flap healing and to gradually fill the expander with physiological saline solution.

Subsequent follow-up visits found no flap healing disorders. Blood supply remained satisfactory, with no postoperative wound dehiscence, pathological discharge, or signs of inflammation.

Three months after the surgery, full integration of the flap with the surrounding tissues was confirmed (fig. 1, fig. 2).

During a follow-up visit, a minor skin inflammation was observed in the form of redness and pain, located at the level of the second intercostal gap, parasternally on the right side, superiorly and medially in relation to the myocutaneous island (fig. 3). Therapy with nonsteroidal anti-inflammatory drugs at standard doses was recommended, with improvement in the following days. A procedure to replace the expander with an implant was planned. Due to the visible asymmetry of

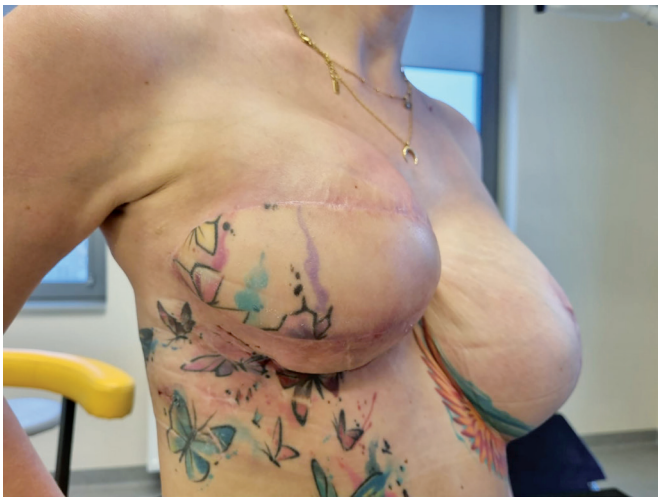

**Figure 1.** Full integration of the myocutaneous flap with the surrounding tissues three months postoperatively

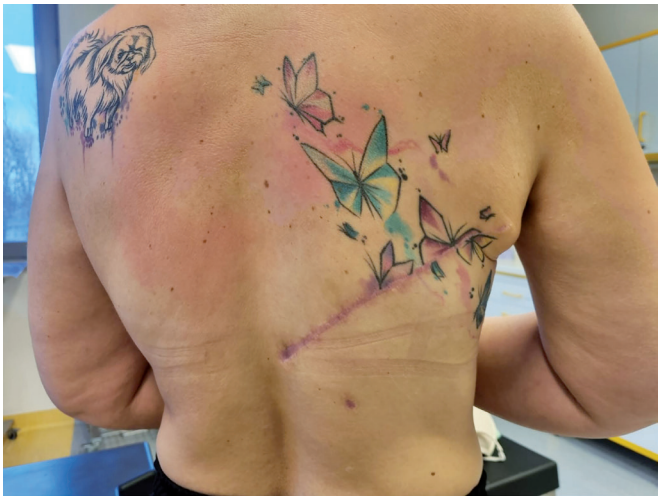

**Figure 2.** Healed scar three months postoperatively

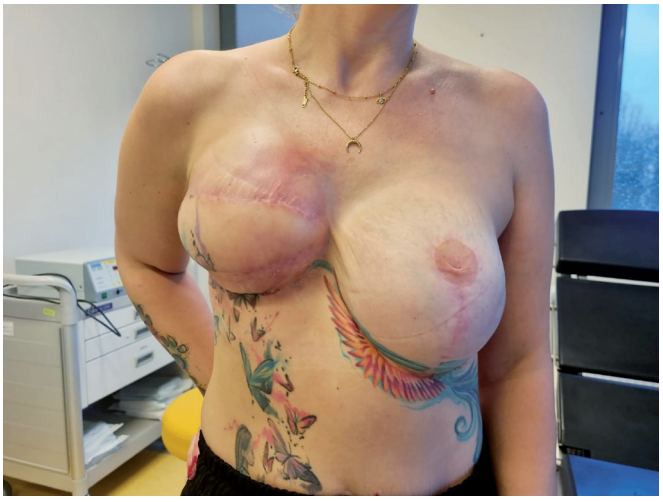

**Figure 3.** Three months postoperatively, a slight skin inflammation in the form of redness and pain, located in the area at the level of the second intercostal gap, parasternally on the right side, superiorly and medially in relation to the musculoskeletal island

the breasts, another procedure was planned to restore breast symmetry.

## Discussion

In the case described above, an LD myocutaneous flap was used due to the failure of standard breast reconstruction after anticancer treatment. This method was chosen as it was considered an appropriate solution for a patient with questionable quality of breast soft tissues, as well as healing disorders after radiation therapy and a previous infection of the implant site.

In 2022, Słowacki et al. published a paper on the efficacy of the LD flap in patients who underwent a second-attempt implant-based reconstruction (IBR) with or without an LD flap between 2006 and 2019 [5]. The paper has shown that the combination of an LD flap with IBR may offer benefits compared to IBR alone in patients who have undergone radiotherapy in the past, and that the use of an LD flap may reduce the incidence of complications and increase the chance of reconstructive success.

Bacterial infection is a well-known complication with an incidence of 1–43%. *Staphylococcus aureus*, *Staphylococcus epidermidis*, and coagulase-negative staphylococci are the most common pathogens in breast implant infections [6].

In 2022, a study was published that demonstrated the benefits of an LD flap. The paper described a retrospective evaluation of patients who underwent a second attempt at IBR or free flap reconstruction after explantation due to infection between 2006 and 2019 [7]. The authors concluded that given the high failure rate of implant-based breast reconstruction in patients with prior radiotherapy and failure due to infection, autologous reconstruction should be strongly considered in this population.

An LD flap not only ensures a satisfactory aesthetic outcome, but also carries a low risk of complications and offers good healing outcomes. Such conclusions were reached in a publication describing cases of patients who presented for delayed breast reconstruction and underwent LD myocutaneous flap transplantation. The 1999–2007 patient medical records were reviewed for age, type of mastectomy, history of chest wall radiation therapy, reconstruction of the nipple-areola complex, and complications at both the donor and acceptor sites. The researchers concluded that an LD flap provides adequate soft tissue and reliable blood supply to reinforce the missing tissues after mastectomy. It is a safe method of breast reconstruction and an excellent alternative for patients at high risk of complications [8].

This approach is often used for salvage purposes when other breast reconstruction techniques have failed. For example, Chiasson et al. (2020) reviewed the use of an LD flap in combination with prosthetic devices, regardless of the need for adjuvant radiotherapy, and assessed the safety and efficacy of this approach as a primary method of reconstruction. Their conclusions were as follows: autologous tissue alleviates many of the sequelae of radiotherapy. Reconstruction with LD myocutaneous flap

combined with prosthetic devices is a safe option, even in the setting of adjuvant radiotherapy. It has high success rates [9].

Petrescu et al. presented evidence for the efficacy of the LD flap technique. Based on this work, the following conclusions were drawn: careful planning of breast reconstruction using an LD flap in combination with implant reconstruction provides stable outcomes and excellent cosmetic appearance of reconstructed breasts, while minimising the risk of complications. As a result, the quality of life of patients is significantly improved, with relatively rapid social and occupational reintegration [10].

An LD flap is very commonly used for breast reconstruction. This method involves using muscle to vascularize the skin and/or increase the volume of the reconstructed breast [11]. The morbidity associated with the procedure is low, and the surgery is well tolerated even in the presence of risk factors. This is a good option for mastectomy patients seeking breast reconstruction.

Considering factors such as the number of applications and the potential for excellent aesthetic outcomes, the use of LD flaps may be considered as a first-line option in selected patients [12]. An LD flap offers many benefits, including trophicity and very low complication rates [13]. It can be used successfully in women with skin damaged by radiation therapy. In contrast to implant-only reconstruction, this approach provides well-supplied graft, which results in a better aesthetic outcome. The recovery period after implant placement is 6–8 weeks [14]. However, this method may also have adverse effects. Physicians performing breast reconstruction procedures should use knowledge about the complications that occur and clearly inform patients about the benefits and disadvantages of LD muscle transposition [15]. Breast reconstruction using an LD muscle flap offers very good outcomes with a low rate of complications [16].

## Conclusions

Postoperative wound healing disorders after mastectomy with breast reconstruction and radiotherapy pose a serious clinical challenge. The presented method is an appropriate solution for patients with wound healing disorders after radiotherapy and a history of implant site infection, as confirmed in the presented case. The LD flap provides well-supplied tissue of adequate quality to cover the soft tissue defect. In the case of failure of less complex reconstructive approaches, such as free skin grafts or local flap plasty, an LD flap may be an appropriate method for covering tissue defects. The presented breast reconstruction approach not only seems to be a safe and appropriate alternative for patients at high risk of complications, but it also offers satisfactory aesthetic and healing outcomes.

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# INTRACRANIAL DURAL ARTERIOVENOUS FISTULA MANIFESTING AS VISION DISTURBANCES IN A 36-YEAR-OLD PATIENT

## Wewnątrzczaszkowa przetoka tętniczo-żylna opony twardej objawiająca się zaburzeniami widzenia u 36-letniego pacjenta

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**Abstract**

Intracranial dural arteriovenous fistulas are a heterogeneous group of vascular pathologies characterized by abnormal arteriovenous shunts within the dura mater. These pathological connections can occur between arteries of the dura or pia mater and veins or venous sinuses of the dura, cortex, or arachnoid. While some dural arteriovenous fistulas may remain asymptomatic, others can lead to significant clinical consequences. They can manifest in various ways, including ophthalmological symptoms. Non-invasive neuroimaging studies are crucial in their diagnosis, with endovascular therapy being the primary treatment modality. This report presents the case of a 36-year-old patient referred to the neurology department due to bilateral optic disc edema and progressive visual acuity deterioration, later diagnosed with an intracranial dural arteriovenous fistula. Given the rarity of the condition, this case aims to enhance clinicians' understanding of dural arteriovenous fistulas, their diagnostic processes, and treatment strategies.

**Streszczenie**

Wewnątrzczaszkowe przetoki tętniczo-żylne opony twardej to heterogeniczna grupa patologii naczyniowych charakteryzujących się nieprawidłowymi połączeniami tętniczo-żylnymi w obrębie opony twardej. Te patologiczne połączenia mogą występować między tętnicami opony twardej lub miękkiej a żyłami lub zatokami żylnymi opony twardej, kory mózgowej lub pajęczynówki. Podczas gdy niektóre przetoki mogą pozostać bezobjawowe, inne mogą prowadzić do poważnych konsekwencji klinicznych. Mogą powodować różne objawy, w tym okulistyczne. Nieinwazyjne badania neuroobrazowe mają kluczowe znaczenie w ich diagnozie, a podstawową metodą leczenia jest terapia wewnątrznaczyniowa. W niniejszej pracy przedstawiono przypadek 36-letniego pacjenta skierowanego na oddział neurologii z powodu obustronnego obrzęku tarczy nerwu wzrokowego i postępującego pogorszenia ostrości wzroku, u którego później zdiagnozowano wewnątrzczaszkową przetokę tętniczo-żylną opony twardej. Biorąc pod uwagę rzadkość tego schorzenia, przedstawiony opis przypadku ma na celu pogłębienie wiedzy lekarzy na temat wewnątrzczaszkowych przetok tętniczo-żylnych opony twardej, ich procesów diagnostycznych i strategii leczenia.

**Keywords:** central nervous system; dural arteriovenous fistula; vascular malformations

**Słowa kluczowe:** centralny układ nerwowy; przetoka tętniczo-żylna opony twardej; malformacje naczyniowe

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## Introduction

Intracranial dural arteriovenous fistulas (DAVFs) are a heterogeneous group of vascular anomalies characterized by abnormal arteriovenous shunts originating from dural vessels. These vascular abnormalities involve pathological connections between arteries of the dura or pia mater and veins or venous sinuses within the dura, cortex, or arachnoid [1–3]. DAVFs account for 10–15% of all intracranial vascular malformations [3], with an incidence ranging between 0.15 and 0.29 per 100,000 persons per year [3]. While DAVFs are frequently located near dural venous sinuses, they can develop anywhere within the intracranial dura mater [2]. The most common sites include the junction of the transverse and sigmoid sinuses, the cavernous sinus, and the superior sagittal sinus [1, 3, 4]. The clinical presentation of DAVFs varies significantly depending on the fistula's location [1, 3], with symptoms ranging from mild headaches or pulsatile tinnitus to severe complications such as seizures or intracranial hemorrhage [3, 5]. The most common symptom is pulsatile tinnitus, present in 60% of cases [6], but other manifestations, such as intracranial hypertension, speech or language disturbances, cranial neuropathies, and visual impairment, as seen in our patient, are also notable [3]. Studies indicate that 83% of patients with cavernous sinus DAVFs present with proptosis or visual disturbances [7]. More aggressive severe lesions may present with progressive dementia or parkinsonism [6]. Conversely, some DAVFs may remain asymptomatic or even regress spontaneously [1–3, 8].

## Case presentation

A 36-year-old male with no history of chronic illnesses was referred to the Neurology Department at the hospital in Zielona Góra from an ophthalmology clinic due to bilateral optic disc edema without evidence of optic nerve inflammation and progressive bilateral visual acuity deterioration over the past month. Neurological examination on admission revealed no meningeal or pathological signs, aside from the noted visual disturbances. An extensive laboratory workup, including oncological, virological, bacteriological, autoantibody, and thyroid panels, returned negative results.

A series of neuroimaging studies, including orbital magnetic resonance imaging (MRI), cranial computed tomography angiography (CTA), head MRI, and cranial MR angiography (MRA), were performed. Orbital MRI showed a slightly tortuous course of the optic nerves and bilateral dilation of the optic nerve sheaths up to 6 mm, measured in the sagittal plane, and 3 mm posterior to the eyeballs. Additionally, there was bilateral flattening of the posterior poles of the eyeballs at the optic nerve level, suggesting increased intracranial pressure.

In the initial magnetic resonance imaging using SWI/SWAN (Susceptibility Weighted Imaging/Susceptibility Weighted Angiography) sequences, the lesion was not visible, probably due to its location in the immediate vicinity of the skull vault bones. However, given the high sensitivity of these sequences, even small changes of this type may be visible, which may lead to a preliminary diagnosis of a dural arteriovenous fistula.

CTA revealed a tortuous distal course of the left external carotid artery and small, twisted blood vessels in the posterior cranial fossa near the left sigmoid sinus. Early contrast filling of the sigmoid and left transverse sinuses suggested a DAVF (fig. 1).

MRA confirmed the diagnosis, revealing tortuous arteries with segmental dilatation of the left posterior branch of the external carotid artery and branches of the posterior auricular artery within the dural wall at the level of the left sigmoid sinus (fig. 2).

The patient was subsequently referred for neurosurgical consultation and scheduled for fistula embolization. Diagnostic digital subtraction angiography (DSA) confirmed an arteriovenous fistula located on the dural wall near the junction of the left transverse and sigmoid sinuses. The arterial supply was from the external carotid

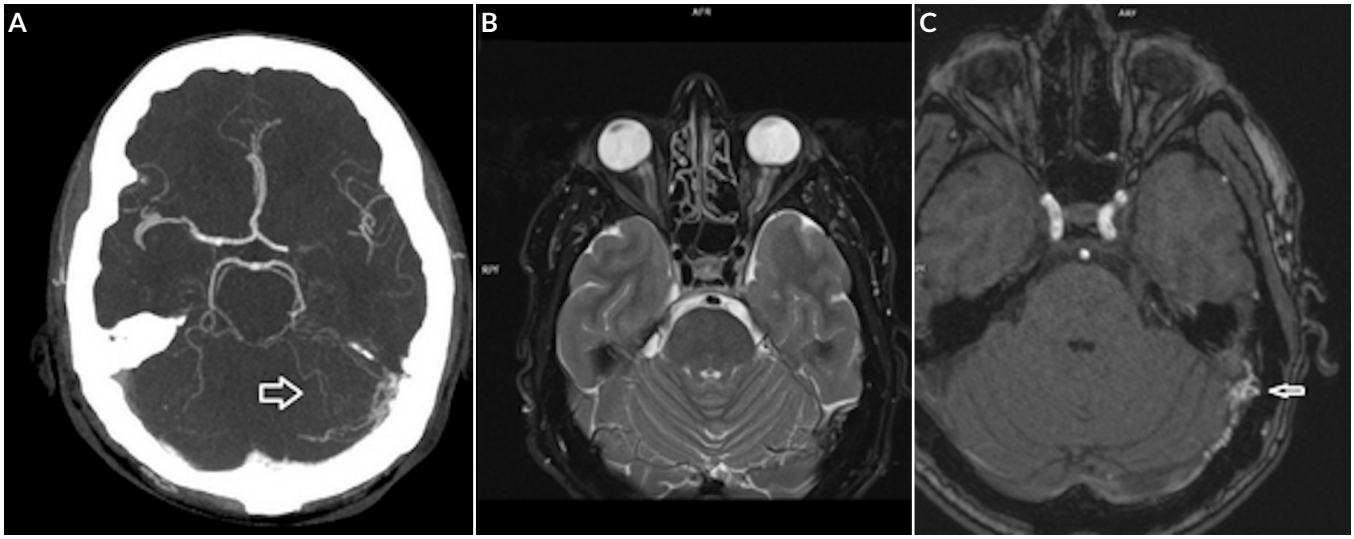


**Figure 1.** Angio-CT and MR scans. **A.** Abnormal vessels in the posterior cranial fossa on the left side during an angio-CT examination of cerebral arteries. **B.** Tortuous course of the optic nerves in a T2-weighted MR image of the orbits. **C.** Arteriovenous fistula in the posterior cranial fossa in the area of the left sigmoid sinus in a TOF (time of flight) angio-MR image

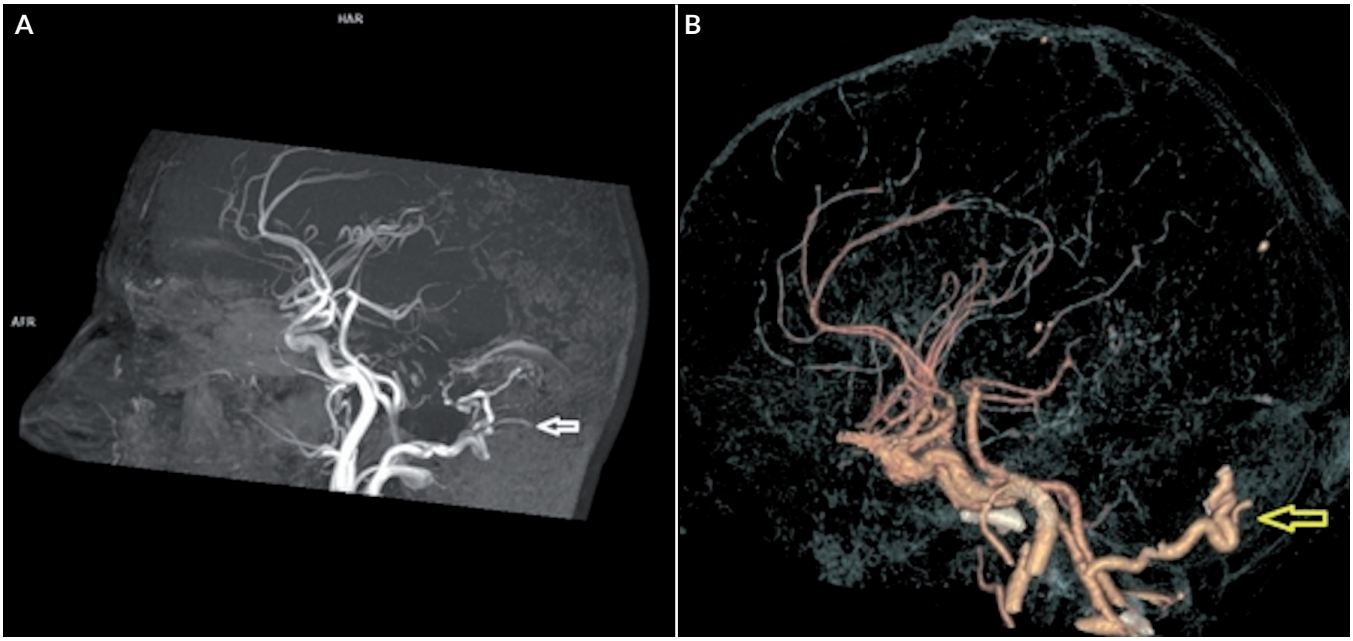


**Figure 2.** Angio-MR and CT angiogram scans. **A.** Image of an arteriovenous fistula in the sagittal plane in the maximum intensity projection (MIP) of an angio-MR (time of flight) TOF examination. **B.** Dilated, tortuous left external carotid artery in a virtual reality (VR) reconstruction of a CT angiogram

artery, small meningeal-hypophyseal arteries, and the left anterior inferior cerebellar artery. Retrograde venous outflow into the transverse sinus and single cortical outflows were noted, classifying the fistula as a Cognard type 2a+b. The fistula was successfully treated with the placement of eight coils, resulting in complete exclusion from circulation. Follow-up angiography demonstrated normal arterial flow. Postoperative ophthalmological assessment showed improved visual acuity and resolution of optic disc swelling.

## Discussion

Dural arteriovenous fistulas (DAVFs) are a rare cause of neurological symptoms that can lead to life-threatening conditions. Although they can occur at any age, DAVFs are more prevalent in men aged 40 to 60 years [3]. Adult-onset DAVFs are typically acquired, while those diagnosed in childhood are considered congenital [6]. The exact etiology remains unclear, but factors such as prior craniotomy, trauma, thrombotic diseases, venous sinus occlusion, tumors, or systemic thrombotic activity have been implicated [1–3]. Elevated levels of cytokines related to neovascularization, including vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (bFGF), may also contribute to DAVF pathogenesis [9]. As inherited thrombophilias are mentioned as risk factors for the development of dural arteriovenous fistulas, a familial history of fistulas may rarely be present [10]. The Cognard and Borden classifications are widely used to predict DAVF progression [1, 3]. Below, we present the Cognard classification, which is based on venous drainage morphology and allows for the estimation of the risk of serious fistula complications (tab. 1).

Spontaneous regression is possible even in more aggressive lesions [1, 8]. However, the type 2 a+b DAVF described in this case carries a 66% risk of cerebral hemorrhage [3].

CTA or MRA are invaluable for the initial diagnosis of DAVF, with typical findings including dilated, tortuous vessels, sinus enlargement, or obstruction [3]. However, definitive diagnosis and treatment planning require digital subtraction angiography, the gold standard for DAVF diagnosis [2, 4].

**Table 1.** Cognard classification of dural arteriovenous fistulas [1, 3]

| Type | Description | Risk of complications |
|---|---|---|
| I | Located in the main sinus, with antegrade flow, without cortical drainage | Mild clinical course |
| IIa | Located in the main sinus, with reflux into the sinus, without cortical drainage | Intracranial hypertension in 20% of cases |
| IIb | Located in the main sinus, with reflux into cortical veins | Hemorrhage in 10% of cases |
| IIa+b | Located in the main sinus, with reflux into cortical veins and into the sinus | Hemorrhage in 66% of cases |
| III | Direct drainage into a cortical vein without venous ectasia | Hemorrhage in 40% of cases |
| IV | Direct drainage into a cortical vein with venous ectasia | Hemorrhage in 65% of cases |
| V | Direct drainage into spinal perimedullary veins | Progressive myelopathy in 50% of cases |

The optimal treatment goal is a complete disconnection of the fistula from its venous drainage. While asymptomatic and low-grade lesions may be managed conservatively with serial monitoring, endovascular therapy (EVT) remains the mainstay of treatment, achieving long-term complete obliteration in 70–90% of cases [5]. EVT can be performed via transarterial or transvenous approaches [3]. Alternative therapeutic options include open surgery and stereotactic radiosurgery [3], with open surgery typically reserved for cases where endovascular approaches have failed or are unfeasible, such as lesions involving the anterior cranial fossa [3]. Stereotactic radiosurgery is particularly effective for cavernous sinus lesions and can be used alone or in combination with endovascular or surgical treatment [7].

## Conclusion

Dural arteriovenous fistulas are complex conditions with diverse symptomatology that are often diagnosed through non-invasive imaging modalities such as CTA or cranial MRA. Endovascular therapy is a highly effective treatment method, often leading to full recovery, except in cases complicated by hemorrhagic stroke.

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