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RATOWNICTWO MEDYCZNE

ALLOPLASTY FOR COMPLEX ABDOMINAL HERNIAS

PROCEDURAL SEDATION ANALGESIA IN PREHOSPITAL SETTINGS
VENTILATOR-ASSOCIATED TRACHEOBRONCHITIS (VAT)

NOVEL WAYS OF APPLYING AI IN EMERGENCY MEDICINE

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ORIGINAL ARTICLE

Alloplasty for complex abdominal hernias in patients with an increased risk of wound infection

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ABSTRACT

Aim: Improvement the effectiveness of the use of alloplasty of complex abdominal hernias in patients with an increased risk of developing wound infection by substantiating a wider introduction of primary alloplasty and reducing the number of postoperative complications.

Material and methods: A retrospective clinical analysis of the results of surgical treatment of 252 patients with complex abdominal hernias, who were operated on by the open method for the period 2010-2020, was carried out. Infringement was occurred in 146 (57.9%) patients, eventration - in 3 (1.2%) patients, stoma - in 3 (1.2%), fistulas - in 9 (3.6%). Obesity was diagnosed in 159 (63.0%) patients, diabetes mellitus - in 27 (10.7%) patients, and steroid use - in 13 (5.2%) patients. In 223 (88.5%) patients, concomitant pathology was found that required combined surgical treatment.

Results: In the early postoperative period, early complications were observed in 21 (8.3%) cases: seroma - in 9 (3.6%) patients, inflammatory infiltrate - in 6 (2.4%), hematoma - in 3 (1.2%), necrosis of the wound edges - in 2 (0.8%), wound suppuration - in 1 (0.4%).

Conclusions: The using of primary alloplasty of complex abdominal hernias in patients with an increased risk of developing wound infection by a special methodology can increase its effectiveness, improve treatment results and reduce the number of complications.

KEY WORDS

alloplasty, defects, wound infection, complications, abdominal wall

INTRODUCTION

Complex abdominal hernias (CAH) are characterized by atypical clinical situations, a more severe course, a tendency to specific complications, relapses that require a comprehensive individual approach [1, 2]. The social habits of patients, their lifestyle, diet, individual physiological, constitutional, medical characteristics play a significant role in the effect of the operation and may be the cause of the development of complications that must be taken into account when performing plastic surgery of the abdominal wall (AW) [1-3].

Alloplasty is an important surgical procedure for restoring tissue integrity in patients with CAH [4, 5]. Various types of alloplasty can close most AW defects, but the focus is still only on the surgical technique. The most common classical methods of alloplasty "onlay", ("inlay", "sublay") are accompanied by different rates of wound complications (WC), such as seroma (18-35%), infiltrate (4-8%), suppuration (5-10%), fistula (up to 6%), chronic pain (6-15%), meshoma [2, 5-8]. Wound infections (WI) associated with mesh implantation can develop both after laparoscopic and open AW alloplasty in the early and late postoperative period [7-9]. Implantation of large meshes causes WC up to 32.4%, WI up to 13.6% [10-12]. The causes of their occurrence are: obesity, smoking, immunosuppression, features of surgical intervention, wide separation of the anatomical structures of the AW, prolonged surgical intervention, the presence of a dormant infection, ligature abscesses, etc. [2, 4, 6, 8, 9]. The development of WI in the area of alloplasty requires repeated surgical procedures and prolonged hospitalization [5, 8, 12].

The presence of CAH with infected or contaminated tissues is a complex surgical problem, and the possibility of AW alloplasty in such cases has not yet been discussed [11, 13]. Often, in the surgical treatment of this category of patients, primary AW alloplasty is not used, so staged operations are performed [3,4,5]. Abstaining from the AW alloplasty due to a high risk of WI, complications from the cardiovascular or respiratory systems is the cause of a significant number (24-65%) of relapses after CAH treatment [8, 9, 12].

Although surgical interventions for CAH are common, the issue of using primary alloplasty in the treatment of patients with an increased risk of developing WI has not been finally resolved, which indicates the need for further study.

AIM

Improving the effectiveness of the use of alloplasty of complex abdominal hernias in patients with an increased risk of developing a wound infection by sub-

stantiating a wider introduction of primary alloplasty of the abdominal wall and reducing the number of postoperative complications.

MATERIALS AND METHODS

A retrospective clinical analysis of the results of surgical treatment of 252 patients with CAH who had an increased risk of developing of WI was performed. All of them were operated on in an open way in the surgical department of the 1st city clinical hospital in Poltava for the period from 2010 to 2020. There were 197 women (78.2%), men - 55 (21.8%). The patients' age ranged from 21 to 85 years (mean age 63±2.3 years). The duration of the disease ranged was from 2 months to 47 years. Postoperative CAH (PCAH) prevailed – 204 (81.0%). Recurrent CAH was detected in 55 (21.8%) patients, and in 41 (16.3%) of them after preliminary performed AW alloplasty. Median CAH (M) was observed in 228 (90.5%) patients, lateral (L) - in 24 (9.5%). According to the size of the main defect, they were divided into: W1 - 22 (8.7%), W2 - 201 (79.8%), W3 - 30 (11.9%) episodes. Diastasis of the rectus abdominis muscles was diagnosed in 193 (76.6) patients.

According to the VHWG criteria [9], all patients were divided into 4 groups: stage 1 - 35 (13.9%), stage 2 - 76 (30.2%), stage 3 - 123 (48.8%), and stage 4 - 18 (7.1%) cases.

A history of WI in patients with CAH was found in 32 (12.7%) cases. Clinical signs of WI were: wound suppuration - 12 (4.8%) cases, inflammatory infiltrates - 9 (3.6%), ligature fistulas - 8 (3.2%), trophic ulcers in the area of the postoperative scar in 4 (1, 6%) of patients.

146 (57.9%) patients with strangulated CAH (SCAH) were urgently operated on. The hernia incarceration period was from 1 to 48 hours. Necrosis of the strangulated organ requiring its resection occurred in 11 patients (4.4%). In 16 (6.4%) patients, inflammation of the hernia sac and surrounding tissues was observed. Intestinal obstruction was found in 6 (2.4%) patients, serous peritonitis - in 4 (1.6%) patients.

Eventration occurred in 3 (1.2%) patients (as a result of hernia rupture - in 2 (0.8%) of them), fatigue - in 3 (1.2%), ligature fistulas - in 6 (2.4%), enteric fistulas - in 3 (1.2%), in 2 (0.8%) of them - after alloplasty. In 92 (36.5%) patients, a pronounced lower skin-fat fold of the abdomen with macerations, superficial infected wounds under it was determined.

Concomitant diseases were found in 194 patients (77.0%). Obesity of various degrees was diagnosed in 159 (63.0%) patients: 1st degree - in 61 (24.2%), 2nd - in 40 (15.9%), 3rd - in 52 (20.6%). Diabetes mellitus (DM) occurred in 27 (10.7%) patients. 13 (5.2%) patients took steroids for a long time. 36 (14.3%) patients indicated long-term smoking (4 cigarettes per day). 48 (19.1%) patients had previously been operated on for oncopathology, 34 (13.5%) of them received courses of chemotherapy and radiation therapy during the previous year.

In 223 (88.5%) patients with CAH, concomitant pathology was found that required combined surgical treatment. The AW deformity of various origins requiring surgical correction was detected in 182 patients (72.2%). 42 (16.7%) patients with CAH had intra-abdominal pathology, the most common - cholelithiasis - 21 (5.5%) cases, and 6 (2.4%) had acute destructive cholecystitis.

All patients were examined clinically, laboratory, bacteriologically, instrumentally, also determined intraoperative, morphological factors.

When performing surgery for CAH, the following procedures were performed: surgical access to the AW defect with mandatory dermatolipectomy; wide mobilization of the edges of the defect, treatment of the hernia sac; if necessary - hernia laparotomy for revision, viscerolysis, performing simultaneous intra-abdominal operations; the AW alloplasty; active drainage of the implantation zone; layer-by-layer suturing of the wound and its drainage if necessary.

RESULTS

Modified abdominoplasty was performed in 188 (74.6%) patients with CAH. There were types of dermatolipectomy performed in patients with CAH : according to Babcock - 89 (35.3%), according to Fernandez - 65 (25.8%), according to Kelly - 21 (8.3%), according to Torek - 7 (2, 8 %), according to Berson - 4 (1.6%), according to Grazer - 2 (0.8%). In 203 (80.6%) patients, reconstructive alloplasty techniques were used, in 42 (16.7%) patients - reconstructive-corrective, and in 7 (2.7%) - corrective. The following types of alloplasty were performed: onlay - in 3 patients (1.2%), sublay - in 209 (82.9%), sublay-inlay - in 31 (12.3%), inlay - in 6 (2.4%), open IPOM plus – in 3 (1.2%). Separation of anatomical components was performed in 17 (6.8%) cases.

The effectiveness of the treatment of these patients was assessed by studying the number of postoperative complications, postoperative mortality, and relapses.

Local complications were observed in 21 (8.3%) episodes in the early postoperative period: seroma - in 9 (3.6%) patients, inflammatory infiltrate - in 6 (2.4%), hematoma - in 3 (1.2%), necrosis of the edges of the wound - in 2 (0.8%), suppuration of the wound - in 1 (0.4%). General postoperative complications were noted in 10 (4.0%) episodes: abdominal compartment syndrome - in 2 (0.8%), PE - in 2 (0.8%), pneumonia - in 2 (0.8%), acute thrombophlebitis of superficial veins of the lower extremities - in 1 (0.4%), mumps - in 1 (0.4%), acute myocardial infarction - in 1 (0.4%), gastrointestinal bleeding - in 1 (0.4%). 3 (1.2%) patients died. Mortality was associated with certain features of comorbidity, in connection with the technique of the operation, we observed.

In the remote period, 11 (4.4%) local complications were registered: recurrence - 5 (2.0%); long-term deep seroma of the implantation zone - 2 (0.2%); ligature fistulas with recurrent phlegmon of the AW - 2 (0.8%); abscess formation in the implantation zone - 1 (0.4%), "meshoma" - 1 (0.4%).

In the bacteriological study, monoculture dominated (71.4%) with a relatively equal part of the inoculation of Gram-positive aerobic cocci and Gram -negative aerobic bacilli. Anaerobic microorganisms were not detected. When studying sensitivity to antibiotics, the effectiveness of drugs in relation to pathogens of purulent-septic complications decreased in this sequence: cephalosporins of the III-IV generation (73.4-88.1), aminoglycosides (78.4-86.5), fluoroquinolones (62 4 % -69.3%), penicillins (53.8% -56.7%).

In patients with signs of a chronic inflammatory process in the area of the AW defect, radical surgical debridement of the purulent focus was performed simultaneously with dermatolipectomy and herniotomy. In patients with fistulas, the fistulous tract was stained with dye before the start of the operation. During dermatolipectomy, deformed cicatricial tissues of the AW together with the fistulous tract and its branches were excised in one block. Areas with the presence of foci of chronic infections - abscesses, granulomas, ligature infiltrates, were widely cut out with the surrounding tissues, carefully observing the rules of asepsis and antisepsis and trying not to open them. These tissues were further studied morphologically and bacteriologically.

A cicatricially altered greater omentum was often accompanied by signs of chronic inflammation and promoted fusion with other organs. In the presence of inflammatory and cicatricial changes in the great cap, 119 (47.2%) patients underwent its resection. During the implementation of adhesiolysis in 8 (2.1%) cases, intestinal deserosis was observed - the damaged serous membrane was sutured with thin interrupted gray-serous sutures. In 2 (0.8%) cases, there was damage to all layers of the small intestine wall, which required double-row sutures. In 2 (0.8%) patients, resection of delimited connected conglomerates was performed with the formation of entero-enteroanastomosis.

The generally accepted tactics of surgical treatment of SCAH with the presence of infected tissues often limits the use of one-stage AW alloplasty and provides for a staged treatment. The assessment of the state of the restrained organs and their surrounding tissues of the AW was of great importance in choosing the method of operation. The main criteria for performing alloplasty in SCAH there were: the use of wider accesses with the maximum possible excision of infected and necrotic tissues, the mandatory removal of the hernial sac, the use of "lightweight" meshes with large meshes, adequate active drainage of the implantation zone, and targeted antibiotic sensitivity of the microflora.

The use of the AW alloplasty in case of SCAH in the presence of signs of acute intestinal obstruction required the placement of a nasogastric tube, "sucking of intestinal contents" into the stomach with its subsequent evacuation through the tube in 11 (7.5%) patients, and nasogastric drainage in 3 (1,2%) patients, which made it possible to perform tension-free alloplasty and prevent increased intra-abdominal pressure.

Because wound infection increases the longer this one remains open, the duration of surgery is an independent predictor of WI. Therefore, they tried to minimize the time of surgical intervention due to the unification of the methodology, the coherence of the work of the operating team. Thus, the average time for performing a surgical intervention was 107±14 minutes. The average duration of surgical intervention in combined operations increased by 1.2 times and amounted to 132±16 min.

A certain criterion for the state of the site of alloplasty was the duration of discharges along the drains, as well as their nature and volume. In 234 (92.9%) patients, the period of functioning of the drains was up to 5 days, which indicated a favorable course of the wound process in them. In 18 (7.1%) patients, the period of exudative inflammation was longer: by the 7th day, the drainage tubes were removed in 15 (6.0%), and in 3 (1.2%) they functioned for more than 8 days.

An important point in the prevention of hematomas and seromas was considered to be early bandaging of the abdomen, starting from the 1st day after the operation.

In the complex of measures for the prevention of WC in the early postoperative period, infrared monitoring and ultrasound of the AW were used. 137 (54.4%) patients with CAH after alloplasty underwent ultrasound of the implantation zone, which made it possible to assess the structures of the AW tissues and determine the presence of fluid formations in different layers of the postoperative wound. During ultrasound of the AW in 17 (6.7%) patients, focal accumulation of fluid was detected, which was an indication for its puncture. In 11 (4.4%) cases, a single seroma puncture was successful, and in 5 (2.0%) cases, there was a need for repeated punctures (2-4) under ultrasound guidance.

Bacteriological examination of pathological fluids, the content of fistulas, abscesses, and inflammatory tissues of the AW included determining the species nature of the infectious agent, as well as assessing its sensitivity to antibiotics, which made it possible to conduct targeted antibacterial therapy.

The choice of antibiotic therapy depended on the specific clinical situation, taking into account the type and characteristics of the surgical intervention; concomitant diseases; individual clinical situation, sensitivity of microflora, microbial passport of the department. Third-generation cephalosporins were considered priority. Targeted antibiotic therapy optimized the course of the wound process by suppressing infection and limiting the severity of the inflammatory response, which ensured a reduction in the period of exudative inflammation and healing without WC.

DISCUSSION

Contamination may be present at the very beginning of CAH treatment for concomitant chronic infected wounds, trophic ulcers of the AW, stoma, and ligature, in-

testinal, pancreatic, or biliary fistulas [2, 3]. The presence of SCAH, especially a large one; with inflammatory processes of AW tissues; PCAH, especially recurrent, with signs of an infected mesh after preliminary alloplasty; hernia rupture; eventrations; defect associated with acute tissue loss after severe trauma or tissue necrosis of the AW; the AW defect in combination with acute surgical pathology requiring urgent surgical treatment always raises the question of the possibility of implanting alloplastic material in this category of patients. Any clean operation can become contaminated in the presence of cold abscesses that open during the operation after an accidental intestinal injury or bowel resections with anastomoses, when performing simultaneous operations [5, 6]. In patients at increased risk of WI, these procedures may be more complex and require a special approach [7, 8, 11].

The traditional approach to surgical treatment in the presence of contamination greatly limits the use of primary AW alloplasty and implies a staging component [8, 14]. Reconstruction of complex contaminated AW defects has certain features; therefore, in order to minimize infection in such cases, we consider it extremely necessary to apply sequential actions according to a certain algorithm. In patients with CAH, considerable attention was paid to WI prevention measures, which were divided into several stages: before, during, and after surgery [6, 8, 11]. We have developed and substantiated a comprehensive program of surgical treatment of CAH using alloplasty in patients with an increased risk of developing WI. It includes the stages of clinical, laboratory and instrumental diagnostics of such patients, the volume and nature of their preoperative preparation, the features of the AW alloplasty technology in infected tissues, as well as postoperative care with an emphasis on the prevention of WC [6, 14].

Before the operation, it was necessary to sanitize the foci of infection - macerations, wounds, trophic ulcers, fistulas, and stoma. A few days before the operation, the skin of the abdomen and folds were washed under the shower with brushes with antibacterial soap, after which they were treated with Betadine. Twenty minutes before the incision, a double single dose of a broad-spectrum antibiotic was administered intravenously; when an AW defect was identified, ornidazole was additionally administered. Also, to prevent secondary infection in patients with CAH and a high risk of infectious complications, intensive bowel preparation was performed before the AW alloplasty [6, 7, 14].

In our opinion, in order to reduce the amount of WC, the methodology of the operation has a leading role [3, 5, 7]. Properly selected, planned and methodologically performed incision with excision of excess skin-fat, infected tissues is important for the formation of adequate flaps, further adaptation of the wound edges without tension, the possibility of their suturing without residual cavities, prevention of suture eruption, which is an essential moment in the prevention of development [6, 8, 11]. In all cases, the surgical wound was protected according to a special technique, using a special disposable surgical dressing with self-fixing adhesive tapes around the perimeter, with Ioban (3M) protective film pasted on the surgical field, layer-by-layer wrapping of the wound with diapers and napkins, fused with antiseptics [14].

For patients at increased risk of WI, it is important to consider factors that affect the interaction of the implant material with the AW tissues and the possibility of integration without WC. We believe that in these patients it is advisable to use polypropylene meshes with large meshes [4, 12, 14].

The choice of alloplasty was obviously dependent on the area of the defect, its size, shape, morphological state of the AW tissues, the possibility of suturing them without significant tension, creating the optimal volume of the abdominal cavity, and the likelihood of postoperative complications. The following were also taken into account: the severity of diastasis of the rectus abdominis muscles, the degree of intra-abdominal pressure before, during and after the operation, BMI, the age of the patient, and the characteristics of the personal clinical situation [5, 6, 14].

The implementation of clear actions according to a certain algorithm encourages the use of alloplasty even in an infected field. The use of a differentiated approach made it possible not only to reliably close defects of various localization and size, but also to simultaneously eliminate comorbidities requiring surgical treatment and save patients from repeated operations and associated complications, emotional and financial stress [6, 8, 12].

Considering the issues of closing and draining the wound, we proceeded from the following principles: minimizing the presence of foreign bodies in the wound cavity, the use of modern atraumatic hyporeactive suture material, complete adaptation of the walls and bottom of the wound, the elimination of cavities and pockets in the wound, ensuring the outflow of exudate during the first postoperative day, prevention of violations of microcirculation of the skin and subcutaneous layer [2, 8, 11]. The wound was drained through additional holes with silicone tubes with active aspiration of secretions. During the construction of the edges of the skin, in order to prevent microcirculation disorders, brackets were applied in recent years, which made it possible to prevent necrosis, create better conditions for the regeneration of the wound edges, and reduce the time of the operation [6, 7, 12].

Therefore, taking into account the individual characteristics of each patient, the use of a differentiated approach to the selection of the optimal treatment technology before, during and after surgery, allows more widespread implementation of simultaneous alloplasty for CAH in patients with an increased risk of developing of WI and minimizes the number of WC to 8.3% and relapses up to 2.0%.

CONCLUSIONS

The data on the effectiveness of primary alloplasty in complex abdominal hernias in patients with an increased risk of wound infection have been supplemented. The results of alloplasty significantly depend on the correct solution of the planning problem and the choice of the most rational treatment tactics. It has been shown that the application of the proposed prophylactic treatment principles at all stages in 91.7% of these patients allows one-stage alloplasty of the abdominal wall to be performed without early complications and improve treatment results.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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ORIGINAL ARTICLE

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Kalemia – safety aspects of patients hospitalized in Department of Internal, Autoimmune and Metabolic Diseases of Medical University of Silesia in Katowice Clinical Center in the year 2020

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ABSTRACT

Aim: The aim of the study was to present the issue of kalemia compartment disorders in patients hospitalized in a hospital clinical ward who came to the hospital from various areas of pre-hospital care.

Material and Methods: Relying on data of patients hospitalized in the Department of Internal, Autoimmune and Metabolic Diseases of Medical University of Silesia in Katowice Clinical Center in 2020 a retrospective research regarding patients with potassium management disorders has been conducted. Medical documentation of patients admitted with hypo- or hyperkalemia has been reviewed. Range of 3,5–5,0 mmol/l (mEq/l) has been considered a variable identifying high and low potassium concentration. Total number of patients with potassium level disorders was 172 (19,5%) out of 883 patients hospitalized.

Results: Hyperkalemia has been diagnosed in case of 67 patients, hypokalemia in case of 105. The majority of patients with potassium level disorders were aged between 61 and 80. Patients with hyperkalemia were most frequently redirected to hospital from Primary Healthcare facilities. Patients with hypokalemia were most frequently handed over by Emergency Medical Service rescue team. The most common ailments among each age group were weakness and shortness of breath. Main comorbidities among patients with potassium management disorders were renal failure and high blood pressure.

Conclusions: Electrolyte imbalance is common among hospitalized patients. Individuals aged 61-80 are at particularly high risk of potassium management disorders. Renal failure, heart failure and high blood pressure are conditions which most frequently coexisted with potassium management disorders

KEY WORDS

hypokalemia, hyperkalemia, electrolytes

INTRODUCTION

Acid-base homeostasis is greatly dependent on proper concentration of minerals, which play a major role in many biochemical processes [1].

Potassium is the most important inter-cellular component. There are about 3000mmol of this element in human organism, 98% in inter-cellular fluids, the remaining 2% outside cells – in serum.

Potassium, a cation, conducts electrical impulses generated within muscles and nerves. Either too high and too low level may lead to serious and threatening complications, such as arrhythmia. Risk of electrolyte disorders is increased among patients with coexisting conditions such as: renal failure, heavy burns, circulatory insufficiency and diabetes. Potassium sustains osmotic cell pressure and is necessary for the whole line of enzymes to function. Moreover it plays major role in protein synthesis and consumption of carbohydrates.

In physiological conditions potassium is eliminated mainly by kidneys. Only about 10% of potassium is eliminated in stool. During diarrhea or gastrointestinal disorders this figure may become significantly increased, leading to severe complications. The following factors influence concentration of potassium within the organism:

- Acidosis – related to high potassium concentration, alkalosis with low
- Aldosterone, which facilitates elimination of potassium by kidneys
- Insulin, which facilitates glucose absorption also increases absorption of potassium to cells.

The most frequent causes of hypokalemia are: insufficient potassium supply in diet, advanced alcoholism, anorexia, magnesium deficiency, prolonged vomiting and diarrhea. It can be also related to renal potassium loss related (among other reasons) to the use of dehydrating agents, steroid therapy, over-medication in hy-

perkalemia, hyperaldosteronism or diabetes insipidus. The most common causes of hyperkalemia: use of potassium-saving diuretics, angiotensin-converting-enzyme inhibitors, electrolyte drinks, acute kidney injury, chronic kidney disease or aldosterone deficiency. Moreover, increased potassium concentration is related to acidosis, tissue decomposition (in case of neoplasm tumor lysis or leukemia cells breakdown), in hemolysis (decomposition of erythrocytes in blood vessels, breakdown of major hematoma), diabetic acidosis from insulin deficiency, metabolic acidosis (in intoxication or sepsis) and in crush syndrome rhabdomyolysis. It is worth noticing that hyperkalemia may be caused by pre-laboratory mistake, such as keeping arm tourniquet for too long or storing blood for more than hour before testing. Hypokalemia is related to malnutrition-inflammation-cachexia syndrome. Hypokalemia is frequently coexisting with other metabolic disorders related to impaired renal function (such as hyperphosphatemia and acidosis). All these factors, underlying improper potassium level, are related to increased risk of death of any cause.

Whenever improper potassium concentration is suspected, it is advised to determine the level of: electrolytes, urea, creatinine, creatine phosphokinase, phosphates and glucose. It is recommended to undertake urinalysis and make ECG. Both hyperkalemia and hypokalemia need to be excluded in all cases of arrhythmia or cardiac arrest.

Sodium, calcium, magnesium and potassium ions participate in conducting impulses in cardiac muscle cells. Two types of action potentials appear in cardiac muscle: fast and slow. Fast action potentials appear in atrial cells of atriums, ventricles and Purkinje fibers. They allow relatively fast conduction of impulses. Sodium channels located in cell membrane are responsible for fast action potentials. Slow action potentials appear in the cells of sinoatrial and atrioventricular nodes. Cells of these structures do not contain fast sodium channels, but only slow calcium and sodium channels. In pathological conditions, especially ischemia, damage or electrolyte disorders within any section on cardiac muscle, slow action potentials can be observed. Specific changes in 12-lead ECG are dependant on concentration and onset of changes in potassium concentration within patient's organism. Very frequently changes are observed among patients whose potassium ion concentration in serum exceeds 6,7 mmol/l.

Changes in ECG (Fig.1-4):

a) Hypokalemia:

- U-wave,
- T-wave flattening,
- ST segment changes,
- arrhythmia, especially among patients treated with digoxin,
- cardiac arrest (PEA, VF/pVT, asystole) [2];

b) Hyperkalemia:

- first degree AV block (PQ interval >0,2 s),
- P-wave flattened or not present,
- tall, peaked T-wave (higher than R-wave in more than one lead),
- ST segment depression,
- sinusoidal conjunction of S and T waves – "saxophone syndrome",
- widening of QRS complex >0,12 s,
- supra-ventricular tachycardia,
- bradycardia,
- cardiac arrest (PEA, VF/pVT, asystole).

In case of hyperkalemia patients may have symptoms of weakness leading to flaccid paralysis, paresthesia or deep tendon reflex weakening. Decrease in serum potassium ion concentration initially causes malfunction regarding nerve fiber and muscle cell function, leading to exhaustion, fatigue, lower extremity muscle cramps and constipation. In case of severe hypokalemia (<2,5 mmol/l) rhabdomyolysis, paralysis or breathing disorders may appear.

AIM

The aim of the study was to present the issue of kalemia compartment disorders in patients hospitalized in a hospital clinical ward who came to the hospital from various areas of pre-hospital care.

MATERIAL AND METHODS

Research has been conducted in the Department of Internal, Autoimmune and Metabolic Diseases of Medical University of Silesia in Katowice Prof. K. Gibiński Clinical Center in 2021 and 2022. Patients' treatment history from the year 2020 was analyzed. Data was gathered in Asseco Medical Management Solutions (AMMS) software, which is used to handle hospital patients' electronic documentation. Out of all 883 patients hospitalized in 2020, 172 had potassium management disorders diagnosed. The 3,5–5,0 mmol/l (mEq/l) range was determined a variable identifying high or low potassium concentration. Among this group the following data was analyzed: gender, age, admission path, ailments most frequent for given age group, ailments most frequent for given gender and the number of deaths. Patients were divided into 4 age groups: below 40, 41-60, 61-80 and above 80. Research was limited by the lack of illness and comorbidity identification due to insufficient information in data source.

STATISTICS

Material has been processed statistically in tables, with the use of Microsoft Excel software, obtaining values assigned to particular criteria.

RESULTS

In the year 2020, potassium management disorders was diagnosed among 172 out of 883 patients of the Department of Internal, Autoimmune and Metabolic Diseases of Medical University of Silesia in Katowice Prof. K. Gibiński Clinical Center.

Table 1. Patients with hyper- and hypokalemia divided by gender.

Gender	Hyperkalemia	Hypokalemia
	Number	Number
F	29	52
M	38	53
Total	**67**	**105**

Table 2. Patients with hyper- and hypokalemia divided by admission path.

Admission path	Hyperkalemia	Hypokalemia
	Number	Number
No data	1	0
Hospice	0	3
Dialysis	3	0
Primary healthcare	30	35
Cross-department Transfer	3	4
Hospital	9	19
EMS team	21	44
Total	**67**	**105**

Table 3. Patients with hyper- and hypokalemia divided by gender and age groups.

Gender	Potassium Level	Age group		
		below 40	below 60	below 80
F	Hyperkalemia	4	7	12
	Hypokalemia		15	29
	Total F	4	22	41
M	Hyperkalemia	4	8	17
	Hypokalemia	7	14	26
	Total M	11	22	43
Total F+M		15	44	84

Table 1 shows gender-divided number of patients with improper potassium concentration. (F- Female, M – Male).

In the group researched, more cases of low potassium concentration have been observed Hyperkalemia was more common among male patients. There was no significant difference in gender among patients with hypokalemia.

Table 2 shows data of patients with potassium management disorders divided by admission path.

Majority of patients admitted to hospital with potassium management disorders were directed from Primary Healthcare Facilities or brought in by Emergency Medical Service rescue teams. Number of patients handed over by EMS teams and transferred from another hospitals was over twice the number of patients with hyperkalemia handed over the adequate way. Three individuals have been admitted to hospital from dialysis center due to hyperkalemia. No patients transferred from dialysis center with hyperkalemia were observed. Three patients with hypokalemia have been admitted from hospice, with no cases of hyperkalemia in this facility.

Table 3 shows patients with potassium management disorders divided by gender and age group

29 patients with hyperkalemia were female. The eldest one was 93, the youngest was 29. 38 patients were male. The eldest was 100, the youngest was 29. Hyperkalemia has been most frequently diagnosed among

Table 4. Ailments reported by patients with hyper- and hypokalemia divided by age group.

Ailments	Hyperkalemia				Hypokalemia	
	below 40	41-60	61-80	over 80	below 40	41-60
Unresponsive	0	0	0	0	0	1
Diarrhea	0	0	0	0	2	2
Abdominal pain	0	0	0	1	1	4
Headache	0	0	0	0	0	1
Chest pain	1	0	0	0	0	0
Muscle pain	9	9	1	0	0	2
No data	2	3	4	0	0	1
Seizure	0	2	2	0	0	2
Dyspnea	1	1	2	2	2	
Fever	0	2	1	0	0	1
Other	0	2	1	0	1	1
Cough	0	0	0	1	0	0
Lower extremity edema	0	2	1	0	0	1
Syncope	0	0	1	0	0	0
Weakness	2	1	7	6	1	8
Anxiety	2	0	3	0	0	0
General condition deterioration	0	0	1	1	0	0
Malaena	0	0	0	3	0	0
Weight loss	0	0	1	0	0	0
Impaired contact	0	1	0	1	0	0
Vomiting	0	0	0	0	0	0
Increased appetite	0	0	1	0	0	0
Contact disorder	0	0	2	0	0	1
Dizziness	0	1	1	0	0	4
Total	**8**	**15**	**29**	**15**	**7**	**29**

patients aged 61-80. Among patients with hypokalemia, 52 were female. The eldest was 93, the youngest was 42. 53 patients were male. The eldest in this group was 91, the youngest was 33. Hyperkalemia has been most frequently diagnosed among patients aged 61-80. Dominant age groups within which patients suffered potassium management disorders were 41-60 and 61-80. The latter had the most numerous cases of hyperkalemia and hypokalemia.

Table 4 presents ailments reported by patients with potassium management disorders divided by age group.

Among all age groups researched, the most common ailments were weakness and dyspnea. Patients with hyperkalemia diagnosed in hospital would most frequently report: weakness, dyspnea, seizures, malaena, lower extremity edema, fever, dizziness, impaired contact, general condition deterioration. Patients with hypokalemia diagnosed in hospital would most frequently report: weakness, diarrhea, abdominal pain, dyspnea, dizziness, muscle pain, contact disorders, seizures.

Table 5 presents ailments reported by patients with potassium management divided by gender.

Among 29 female and 38 male patients with hyperkalemia diagnosed, weakness was the most frequent ailment. Among 52 female and 53 male patients with hyperkalemia diagnosed, the most frequent ailments were: weakness, shortness of breath, abdominal pain and diarrhea.

Table 5. Most common ailments among patients with hyper- and hypokalemia divided by gender.

Gender	Ailment	Hyperkalemia	Hypokalemia
F	Diarrhea	0	5
	Abdominal pain	1	6
	Headache	0	1
	Muscle pain	0	2
	No data	5	2
	Seizure	2	2
	Dyspnea	1	2
	Fever	3	2
	Other	1	4
	Cough	0	1
	Lower extremity edema	0	1
	Syncope	0	1
	Weakness	7	11
	Anxiety	5	2
	General condition deterioration	1	0
	Weight loss	0	1
	Impaired contact	0	1
	Contact disorder	1	2
	Dizziness	2	6
M	Unresponsive	0	1
	Diarrhea	0	6
	Abdominal pain	0	4
	Chest pain	1	1
	Muscle pain	1	5
	No data	4	3
	Seizure	2	1
	Dyspnea	5	7
	Other	2	3
	Cough	1	1
	Lower extremity edema	3	0
	Syncope	1	0
	Weakness	9	14
	General condition deterioration	1	0
	Malaena	3	0
	Weight loss	1	1
	Impaired contact	2	0
	Vomiting	0	2
	Increased appetite	1	0
	Contact disorder	1	2
	Dizziness	0	2
Total		**67**	**105**

Table 6. Most common comorbidity among hospitalized patients with potassium management disorders.

Comorbidity	**Hyperkalemia**	Hypokalemia	Total
Diabetes	5	10	25
Hypertension	19	24	43
Chronic kidney disease	30	16	46
Heart failure	15	17	32
Neoplasm	8	14	22
Total	77	81	158

Table 7. Number of deaths among patients with hyper- and hypokalemia divided by gender.

Gender	**Hyperkalemia**	**Hypokalemia**
F	2	2
M	2	1
Total	**4**	**3**

Table 6 presents the most common comorbidities among patients hospitalized with potassium management disorders.

Most common conditions coexisting with hyperkalemia and hypokalemia were chronic kidney disease and hypertension.

Table 7 presents gender-divided data regarding deaths of patients with potassium management disorders.

Out of 29 female patients with diagnosed hyperkalemia 2 have died (6,9% of research group). Out of 52 female patients with diagnosed hypokalemia also 2 have died (3,4% of research group). Out of 38 male patients with diagnosed hyperkalemia 2 have died (5,26% of research group). Out of 53 male patients with diagnosed hypokalemia 1 have died (1,9% of research group).

DISCUSSION

KALEMIA *VS.* AGE

Research has provided data showing the higher number of patients hospitalized was diagniosed with hiperkalemia than with hypokalemia. Hypokalemia has been diagnosed in case of 52 female and 53 male patients, while in case of 29 female and 38 male patients hyperkalemia has been diagnosed.

In 2007 Vitalinda Pumo et.al. in Tumor lysis syndrome in elderly research have shown that the ability to save potassium is decreased among the elderly. This is confirmed by our research, as the largest group of patients with potassium management disorders were elderly individuals, aged 62-80. The total potassium level in organism is by 20% lower than among younger people. Aldosterone acting on distal renal tubules increases Na2+ reabsorption and facilitates potassium elimination [3]. However age-related decrease in renin and aldosterone may contribute to increased risk of hyperkalemia among the elderly in various clinical conditions.

KALEMIA *VS.* AILMENTS

On the basis of data gathered during the research, major ailments reported by hospitalized patients both with hyperkalemia and hypokalemia in the most common age group (61-80) were: fatigue, shortness of breath, dizziness, contact disorders. Hyperkalemia syndromes are: muscle pain and fatigue (mainly regarding proximal limb sections), paresthesia, arrhythmias (mainly ventricular – bradycardia and ventricular extrasystoles) [4]. Hyperkalemia may be related to: nausea, anorexia, weakness, vomiting, diarrhea, nerve-muscle disorders and cardiac disorders. Other symptoms are: lethargy, muscle fatigue and paresthesia or paralysis and symptoms noticeable in electrocardiography imaging. Increased level of potassium in serum may cause ventricular arrhythmias and lead to sudden death (>8,0 mEq). Low serum calcium level and acidosis may facilitate this predisposition.

Clinical symptoms of hypokalemia comprise changes in the functioning of muscles ans circulatory system as hypokalemia causes hyper-polarization of membrane and disturbs muscle contraction. Moderate hypokalemia (3-3,5 mEq/L) may not cause any symptoms. Mild hypokalemia, (serum potassium concentration between 2,5 and 3 mEq/l) may cause muscle fatigue, cramping and pain (as a result of impaired function of cardiac muscle). There may also be damage to skeletal muscles and constipation (as a result of impaired function of smooth muscles). In more severe hypokalemia flaccid paralysis and weakening of reflexes. Severe potassium deficiency is also related to breathing insufficiency [5].

KALEMIA *VS.* COMORBIDITIES

Data gathered and processed during the research has show that main comorbidities among patients with potassium management disorders are: chronic kidney

disease, cardiac failure, high blood pressure and diabetes. Occurrence of hyperkalemia among patients hospitalized is definitely less frequent than occurrence of hyperkalemia described above.

Presence of such high percentage of patients with hypokalemia may be a result of using diuretics (mainly thiazide) while treating both chronic cardiac insufficiency and hypertension. There are two dominating risk factors of hyperkalemia: drug therapy and chronic kidney disease, frequently not diagnosed earlier [6]. Frequency of hypokalemia combined with chronic kidney disease is very high – between 4% and 24% [7].

Chronic kidney disease is frequently related to renal failure, especially when condition is advanced. Low renal perfusion is syndrome consequence per se or may be secondary to coexisting conditions such as elder age, diabetes and idiopathic high blood pressure [8]. The Cooperative Health Research in the Region of Augsburg, survey number 4 (KORA F4 STUDY) has shown that low concentration of serum potassium caused by taking diuretics is related to increased risk of developing diabetes.

Among individuals with high blood pressure and low potassium concentration there was a significant correlation with pre-diabetic state. No such relevance has been observed in case of individuals with correct blood pressure. It can be assumed that the influence of serum potassium concentration is significant not only for individuals with high blood pressure and insulin resistance underlying both diabetes and hypertension. Patients with hypertension present low concentration of potassium, magnesium and calcium in blood serum and in tissues [9]. Heart failure increases the activity of sympathetic nervous system and the renin-angiotensine-aldosterone system, resulting in potassium concentration decrease.

In one of the analyses completed in the USA, Zillich et. al. have shown strong relation between hypokalemia and glucose intolerance during 59 clinical researches of thiazyde diuretics. This research, along with other results, indicates that treating hypokalemia caused by thiazyde drugs may decrease glucose intolerance and possibly reduce development of diabetes. However no prospective clinical research has shown the influence of diabetes on potassium level functioning [10].

KALEMIA VS. MORTALITY

Research has shown that out of 172 patients hospitalized with potassium management disorders 7 patients have died. Due to potassium role in sustaining resting potential of cell membrane there is high risk of lethal arrhythmias in case of both extreme serum potassium concentration levels occurring. It also needs to be noticed, that relation between improper serum potassium concentration and mortality may be disrupted by other coexisting conditions, which predispose increased risk.

Retrospective research has shown that hypokalemia among patients with NYHA I-III cardiac insufficiency is a considerable, independent risk factor of death directly caused by arrhythmias.

Research by A.J. Collins et al. at Minnesota University, USA, in 2017 has shown that in their research group mortality rate caused by kalemia disorders was a result of comorbidities such as: hypertension, cardiovascular conditions, heart failure, diabetes, chronic kidney disease. 27,6% of patients had potassium level below 4,0 mEq/L, while 5,7% had level of 5,0 mEq/L or more.

Mortality rates regardless of cause by potassium level between 2,5 and 8,0 mEq/l were constant with heart failure (22%), chronic kidney disease (16,6%) and diabetes mellitus (6,6%) vs. control 1,2 and the highest in combined cohort 29,7%. Higher mortality rates were observed among individuals aged 65 or more than in 50-64 range. In corrected model mortality of any cause was significantly increased by each 0,1 mEq/L of potassium concentration change <4,0 mEq/L and ≥5,0 mEq/L [11-13].

LIMITATIONS

Low number of patients and lack of data regarding dietary habits, medication taken ans specific ECG changes were limitations for the research. Obtaining the above-mentioned data in the future would allow continuation of research and deepening the problems related to potassium management disorders among hospitalized patients.

CONCLUSIONS

Research has shown that in 2020 hypokalemia was more frequent diagnose than hypercalemia among patients of the Department of Internal, Autoimmune and Metabolic Diseases of Medical University of Silesia in Katowice Prof. K. Gibiński Clinical Center. Electrolyte disorders are frequent condition among hospitalized patients. Patients aged 61-80 are at particularly high risk of suffering potassium disorders. Chronic kidney disease, cardiac failure and hypertension are conditions frequently coexisting with potassium management disorders.

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CONFLICT OF INTEREST

The Author declares no conflict of interest.

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ORIGINAL ARTICLE

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MEDICAL ACTIVITIES USED BY THE EMT FROM ZYWIEC UNDER 18 YEARS OF AGE IN 2022-2023

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ABSTRACT

Aim: To analyze the interventions carried out by the Medical Rescue Teams in patients under the age of 18 in the operational area of the Medical Rescue Company in Zywiec in the period from January 1, 2022 to December 31, 2023.

Material and methods: The medical documentation of Specialist and Basic Medical Rescue Teams of the Medical Rescue Company in Zywiec in the period from 01/01/2022 to 31/12/2023 (n=23 983) was subject to retrospective analysis. The study included those in which the intervention of the Medical Rescue Teams concerned a patient under the age of 18 (n=1658). The entire analysis was divided into 4 age groups: 0-1, 1-8, 8-13, 13-18 years. In the group division, cards of medical rescue activities were analyzed and divided into the so-called non-traumatic and trauma patient. In the examined medical documentation, an additional division was made into the so-called non-traumatic and traumatic patients. This division was made on the basis of the diagnosis categorized in ICD-10.

Results: On the basis of the date of birth, visits to patients under the age of 18 by Medical Rescue Teams were selected, which accounted for 6,91% of the total interventions in the analyzed period.

Conclusions: Patients under the age of 18 constitute a challenge for Medical Rescue Teams due to a very small number of interventions, which results in the lack of experience in performing examinations and implementing medical rescue activities.

KEY WORDS

Emergency Medical Service in Zywiec, emergency medical teams, pediatric patient

INTRODUCTION

Pre-hospital care is an important link in the chain of human survival, who suffers from a sudden illness or injury. The task of pre-hospital care is to ensure the patient's safety, reverse the current state of emergency health threat and protect against the occurrence of secondary complications of this state by implementing appropriate medical emergency measures (MEM) [1, 2]. Providing care in the form of emergency medical services (EMS) is the responsibility of government administration authorities [3]. There are many pre-hospital care systems around the world that ensure that early interventions and the implementation of appropriate MDGs bring benefits to patients. These systems are subject to continuous analysis and updates, which constantly improves the quality of services provided regarding this care. Since the 1970s, many countries in Europe and around the world have been building their systems on these models [4]. The model for the creation of currently operating emergency medical systems was two main models: the Franco-German Emergency Medical Services System (FGS) and the Anglo-American Emergency Medical Services System [FGS]. AAS]). The FGS system is a system based on the action of an emergency medicine physician. He is responsible for action at the scene of the incident and during transport to the hospital. If paramedics arrive first, they implement MDGs until the doctor arrives [5]. However, the AAS system is closely related with paramedics. Their task is to protect the patient in the hospital in a life-threatening condition and transport to hospital. Rescuers have constant contact with the emergency doctor located in the hospital [6, 7].

In order to provide assistance to every person in a state of immediate health threat in our country, the State Emergency Medical Services system was created. It operates under the Act of September 8, 2006. on the State Emergency Medical Service [1]. This system consists of three basic elements, which include the medical control room, the Medical Rescue Team (EMS) together with the Air Medical Rescue Team and the Hospital Emergency Department (HED) [8]. A person experiencing a sudden

health threat usually has direct contact with three of these links. To run the PRM system first of all, you need to contact the medical dispatcher, where the emergency phone is answered by a medical dispatcher (DM) [9]. After collecting the medical history, the DM decides on the EMT's instructions. After arriving at the scene of the incident, the EMS implements the MCR, and then, if the condition requires it, transports the patient to the Emergency Department. In the Emergency Department, medical triage is performed to determine the priority for implementing initial diagnostics and treatment [10, 11].

According to data provided by the Central Statistical Office (CSO), in 2020, emergency services provided health services at the scene of the incident over 2.8 million times. In 77.9% of cases, these services were provided at the patient's home, the rest in public places, schools or workplaces. From a group of 2.8 million people who need help in pre-hospital care, 4.5% were patients under 18 years of age, a year earlier, patients from this group constituted 6.0% [12]. Related to these statistics, there is little data on the outcomes of prehospital care for patients under 18 years of age. First of all, this is related to a higher percentage of emergencies in adults, which results in a significantly greater number of EMS interventions in adults [13].

A small number of EMS interventions in patients under 18 years of age results in less experience of medical staff in working with this group of patients [13]. This applies in particular to smaller patients below puberty, i.e. the lack of developed pubertal features. In this group, it should be remembered that this is a patient quite different from an adult and many activities performed during the history and physical examination will be different after the implementation of MEM. Caring for an injured or acutely ill child requires a different range of skills than those used by adults, including attention to children's unique characteristics and needs. This may result in the MDGs being used in prehospital care in the youngest will not be performed at the same level as their use in adults. Additionally, the subject of medical training in the field of pediatrics is a small part of the training programs in which EMS staff participate [14-16].

PEDIATRIC PATIENT AND ADULT

A pediatric patient belongs to a very diverse group of patients [16]. The diversity is influenced by the patient's age and weight, which often forces modifications to the medical procedures performed. These people theoretically require the same type of MEM as adults, but due to their different size and anatomy of these procedures are more difficult to perform. Proper care of pediatric patients requires knowledge and experience. It should be emphasized that this is not a miniature of an adult [17].

When talking about an adult patient, we usually categorize him into one group, in which the physical examination performed will vary depending on your health condition. However, pediatric patients are divided into groups depending on age.

Based on the literature, the following division is made:

- Newborn – a child from birth to 28 days of age,
- Infant – a child from 29 days of age to one year,
- Small child – from the first year to puberty, i.e. approximately 8 years of age,
- School children – approx. 8 to 13 years old,
- Youth – from approximately 13 to 18 years of age [18].

The presented research shows that pediatric patients do not understand their health condition compared to adults. The very method of communication with a group of young patients requires adaptation to their age [19]. Certainly, medical care in this group is a more stressful experience for EMS medical staff than for adult patients. In a study conducted by Makhija et al. There are gaps in the elements of preparation for working with children in health emergency situations. EMS members are afraid of implementing the appropriate MDGs, which is often due to the lack of training in the field of pediatric patients. Especially in situations of sudden health threats in children, the factors of fear or lack of experience intensify and largely determine the further performance of MDGs by medical staff from the Emergency Medical Services. They become even more difficult. An example is the indication for peripheral intravenous access. It is identical to that in an adult patient, but children require smaller intravenous catheters and the procedure itself is more difficult [20-21].

When an immediate life-threatening condition occurs, whether in adults or pediatric patients, it is important to take MEM as soon as possible. Any delay in the implementation of a specific medical procedure may result in a decrease in the patient's chances of survival or a return to full health [22]. Good knowledge of appropriate treatment algorithms, including appropriate formulas related to determining vital parameters or selecting equipment in a group of pediatric patients, can significantly improve the speed of actions taken by medical staff [23].

THE AIM

The aim of the study is to analyze the interventions carried out by the Medical Rescue Teams in patients under the age of 18 in the operational area of the Medical Rescue Company in Zywiec in the period from January 1, 2022 to December 31, 2023.

MATERIAL AND METHODS

The medical records of one specialist team and six primary teams from January 1, 2022 to December 31, 2023 (n=23,983) were retrospectively analyzed. The study included those in which the intervention of the above teams concerned a patient under 18 years of age (n=1658) (Fig. 1).

The medical documentation on the basis of which the study was carried out concerned the medical emergency card (MEC) [24]. Medical documentation operates in the PRM system based on the Notice of the Minister

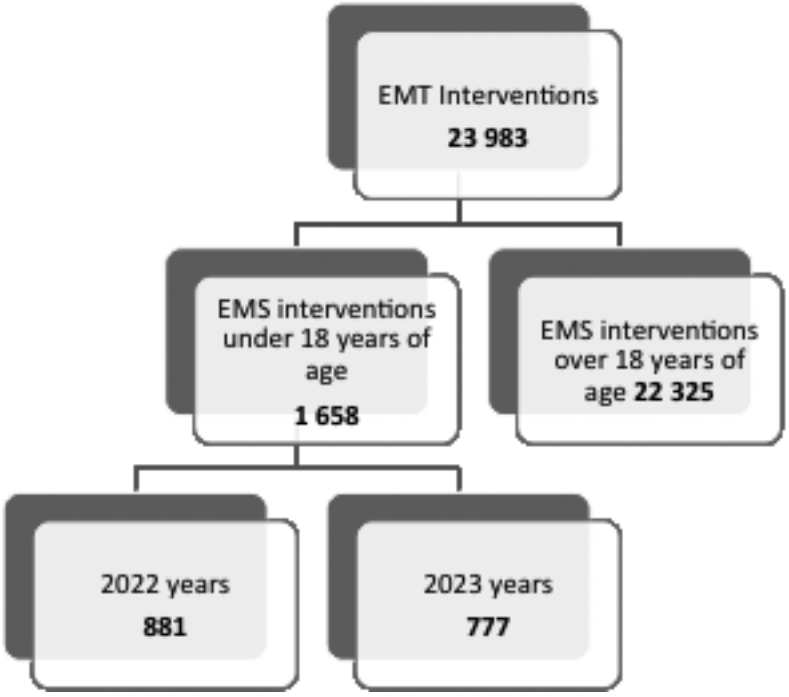


Fig. 1. Interventions EMT in 2022-2023.

of Health of April 22, 2022 on the announcement of the uniform text of the regulation of the Minister of Health on the types, scope and templates of medical documentation and the method of its processing (Fig. 2). MEC is completed in its entirety by the EMS manager. He starts by filling in the patient's personal data. Then fills in the "interview" fields, where the EMS manager describes in detail the elements of the physical examination in the form of a subjective examination. There is a place here for a description of the interview collected from the injured person or a witness of the incident. For patients under 18 years of age most situations will involve gathering information from legal guardians. The next field "examination" includes parts of the physical examination. Here, the EMS manager selects the examined elements and describes the examination performed during the intervention. The next field is "diagnosis", which includes the description and diagnosis based on the ICD-10 code. The ICD-10 code is the International Statistical Classification of Diseases and Health Problems developed by WHO [25]. In Poland, this classification has been in force since 1996. It involves entering the name and statistical number of the diagnosis of a disease, health problem or injury in accordance with the table adopted by WHO. After the "diagnosis" field, there is a "patient management" field, which is used to automatically select the MEMs performed and indicate the pharmacotherapy used.

The overall analysis divided the patients into 4 age groups, which were distributed as follows [18]:

- group of a newborn with an infant up to one year of age (Gr. I: 0-1),
- group of children from 1 to 8 years old (Gr. II: 1-8),
- school age group in the range of 8-13 years (Gr. III: 8-13),
- adolescent age group from 13 to 18 years of age (Gr. IV: 13-18).

In the group division, MEC was analyzed, where the division was made into the so-called non-traumatic and trauma patient. This division was based on the diagnosis categorized in ICD-10 [25]. The following diagnoses were included in the group of non-traumatic patients: A01 to R99, T36 to T88, X40 to X59, Y10 to Y19, Y40 to Y84, Y88 to Z99. However, a trauma patient in ICD10 has the following diagnoses: S00 to T35, T90 to X39, X60 to Y09, Y20 to Y36, Y85 to Y87.

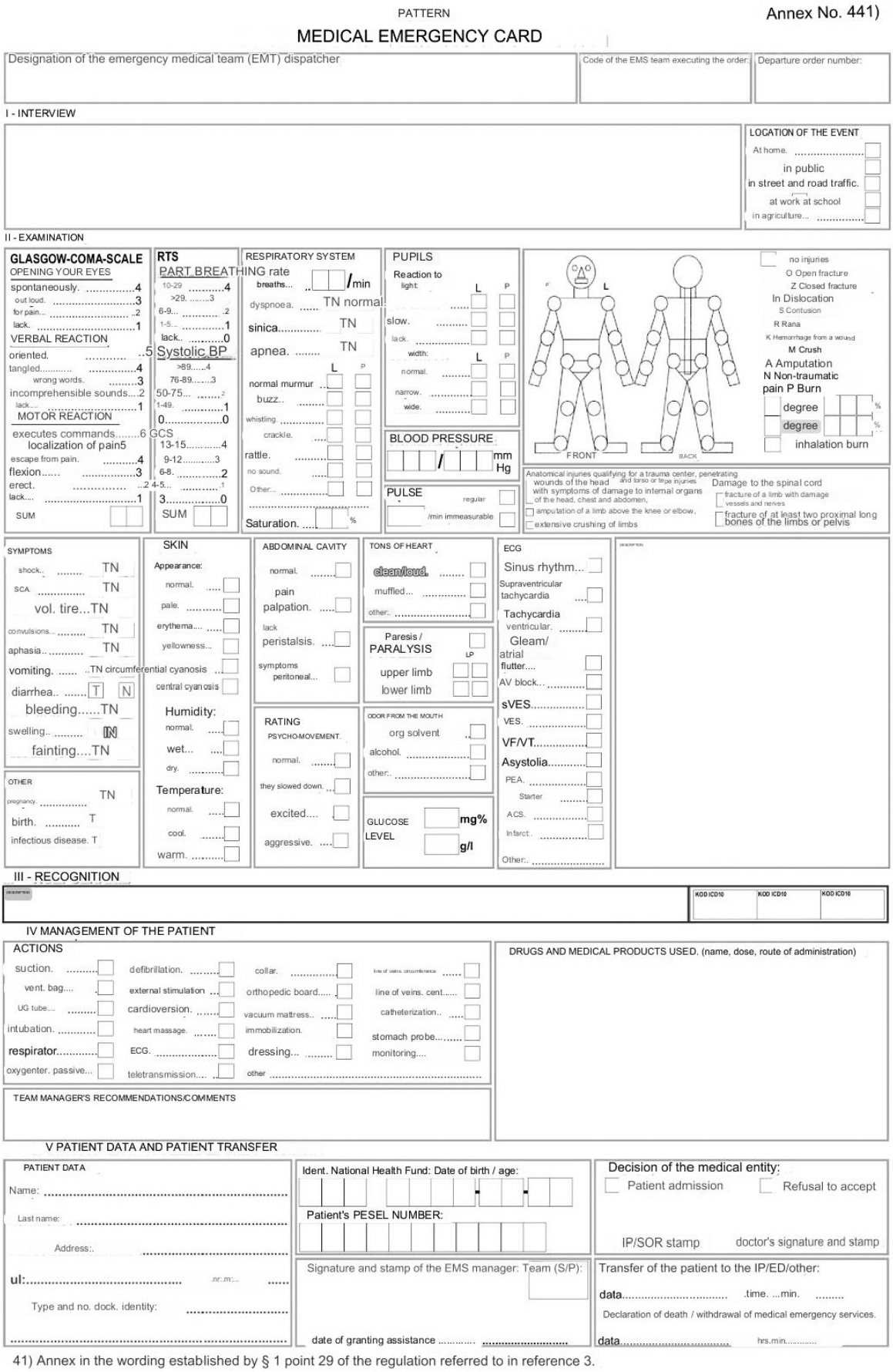
The data used in the study come from 7 EMS teams on 24-hour duty in the Zywiec poviat, located in the Silesian Voivodeship. Of the 7 EMS, one team was EMS S, and 6 were EMS P. They secured approximately 153,000. inhabitants of the Zywiec district (Fig. 2).

RESULTS

The study included 23,983 EMS interventions from the period January 1, 2022 to December 31, 2023 managed by the Emergency Medical Services in Żywiec. From these interventions, EMS trips to patients under 18 years of age were selected based on date of birth, which constituted 6.91% of all interventions in the period under study (Fig. 3). Going further, the division into years was analyzed and months in the studied period (Fig. 4).

Then, patients under 18 years of age were divided into 4 age groups. The decision to divide into age groups was based on medical literature [18]. Patients were classified into 4 groups as described in the material and method.

Medical documentation in the form of KMCR was divided into the so-called non-traumatic and trauma patient. This division was based on the diagnosis categorized in ICD-10 (Fig. 5).



41) Annex in the wording established by § 1 point 29 of the regulation referred to in reference 3.

Fig. 2. Template of the medical emergency card.

Source: Announcement of the Minister of Health of April 22, 2022 on the announcement of the uniform text of the regulation of the Minister of Health on the types, scope and templates of medical documentation and the method of its processing.

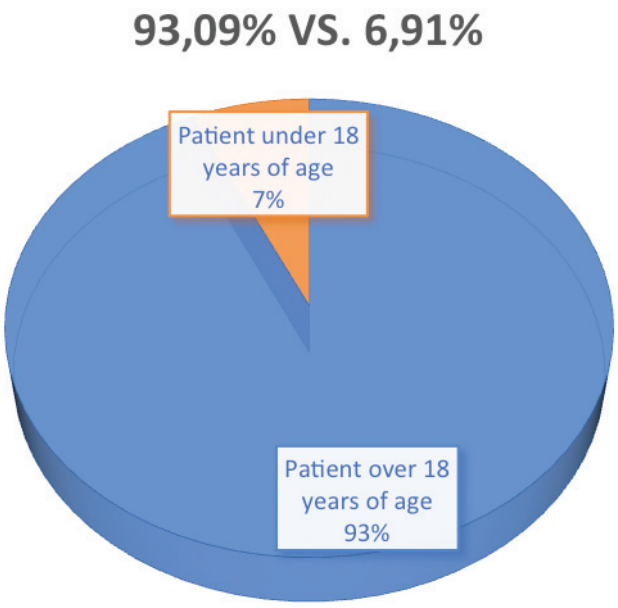


Fig. 3. EMS interventions in the examined period with the division of patients: people over 18 years of age and persons under 18 years of age.

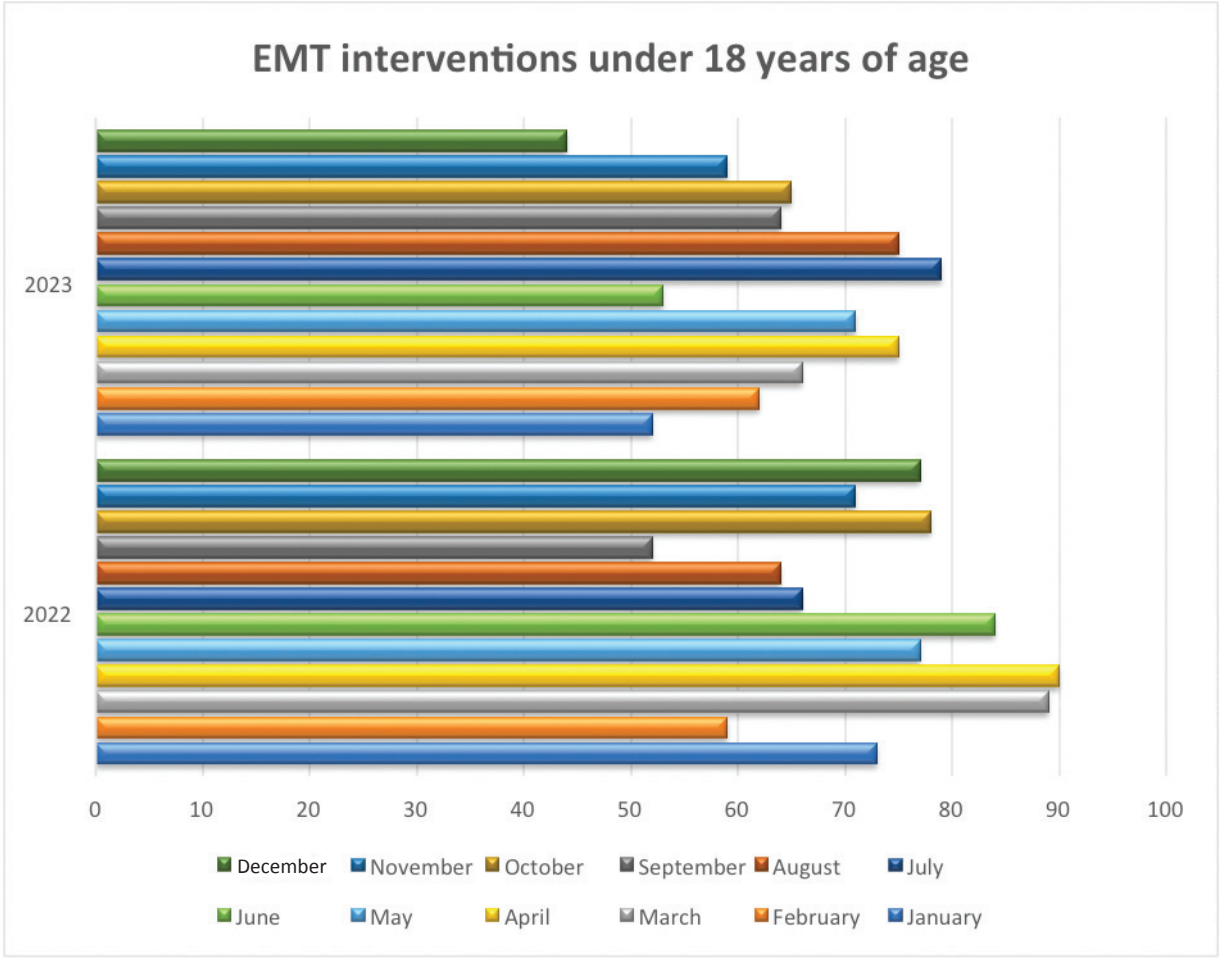


Fig. 4. Analysis of EMS interventions in relation to the number of EMS trips to patients under 18 years of age, divided into specific years and months.

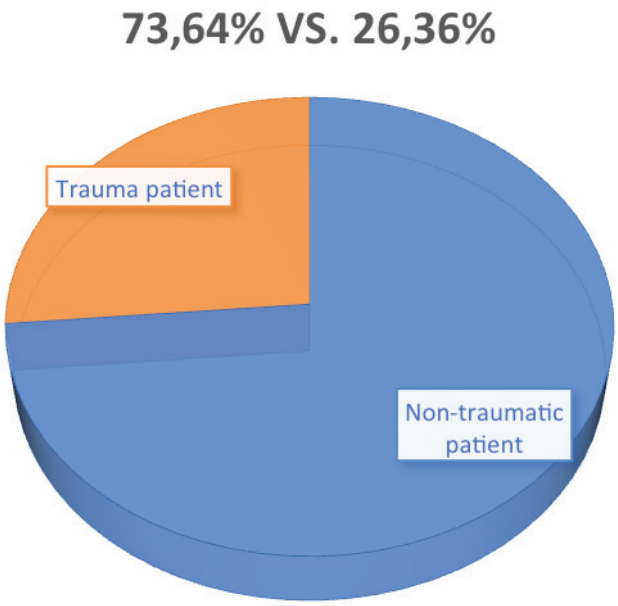


Fig. 5. Division of patient under 18 years of age into non-traumatic (n=1221) and traumatic (n=437) based on ICD-10.

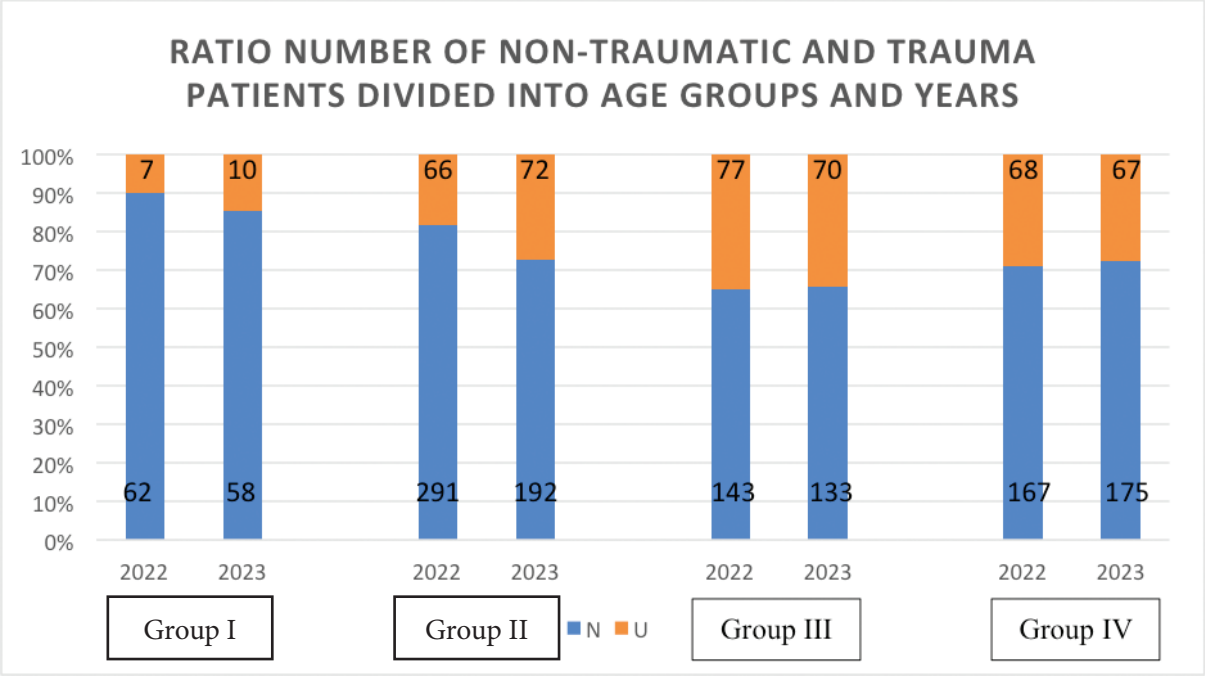


Fig. 6. List of non-traumatic and trauma patients in individual years of the study, divided into age groups.

N – non-traumatic patient

U – trauma patient

Percentage analysis was performed in the division of non-traumatic and trauma patients in individual age groups and years 2022-2023 (Fig. 6). It was observed that the fewest injuries occurred in the group I, and most in the group III. The greatest difference between EMS interventions in the compartment for non-traumatic and trauma patients was observed in group I in 2022 (89.86% vs. 10.14%). The smallest differences in the above-mentioned patients were visible in the group III also in 2022 (65% vs. 35%).

The next analysis included the performance of MEM by the Emergency Medical Services during the intervention in patients under 18 years of age Table 1]. These activities, if performed, were marked by the EMS manager in MED. The analyzed activities include: suction, self-expanding bag ventilation, use of an oropharyngeal tube, endotracheal intubation, connection of a respirator, use of passive oxygen therapy, chest compressions, electrocardiography (ECG), obtaining intravenous access, applying an orthopedic

Table 1. Analysis of the relationship between age groups, including non-traumatic and trauma patients, in relation to the MCR performed.

		GR. I age of 0-1		GR. II age of 1-8		GR. age of 8-13		GR. IV age of 13-18	
		N	T	N	T	N	T	N	T
DRAINAGE	NO	18	120	141	493	149	276	139	346
	YES	0	2	1	2	1	4	0	1
VENTILATION WITH A SELF-INFLATABLE BAG	NO	18	121	141	494	149	277	139	347
	YES	0	1	1	1	1	3	0	0
ORAL-PHARYNGEAL TUBE	NO	18	122	142	493	150	280	139	347
	YES	0	0	0	2	0	0	0	0
ENDOTRAACHEAL INTUBATION	NO	18	122	142	493	150	280	139	347
	YES	0	0	0	2	0	0	0	0
RESPIRATOR	NO	18	122	142	494	150	280	139	346
	YES	0	0	0	1	0	0	0	1
OXYGEN THERAPY	NO	17	111	136	446	148	260	135	339
	YES	1	11	6	49	2	20	4	8
CHEST COMPRESSIONS	NO	18	122	142	494	149	278	139	347
	YES	0	0	0	1	1	2	0	0
ELECTROCARDIOGRAPHY	NO	18	115	137	458	134	203	126	241
	YES	0	7	5	37	16	77	13	106
DEFIBRILLATION	NO	18	122	142	495	150	280	139	347
	YES	0	0	0	0	0	0	0	0
INTRAVENOUS CANNULA	NO	17	116	116	432	102	180	54	188
	YES	1	6	26	63	48	100	85	159
AN ORTHOPAEDIC COLLAR	NO	18	122	142	495	144	280	133	347
	YES	0	0	0	0	6	0	6	0
VACUUM MATTRESS	NO	18	0	142	495	150	279	135	347
	YES	0	122	0	0	0	1	4	0
IMMOBILIZATION	NO	18	0	129	495	121	279	103	346
	YES	0	122	13	0	29	1	36	1
DRESSING	NO	17	121	97	492	112	277	110	339
	YES	1	1	45	3	38	3	29	8

collar, using a vacuum mattress , immobilization and application of a dressing.

DISCUSSION

The State Emergency Medical Services provides protection for the patient in any state of health threat. A health emergency may occur at any time. Illness or injury may contribute to this condition. Regardless of the patient's age, the disease may worsen or an event may occur resulting in an injury in the form of an accident, fall, impact, etc. During the analysis of the literature related to the subject of the work, publications describing patients under 18 years of age were observed, which specified: that the most common reason for EMS intervention is caused by injuries [26-27]. In order to ensure thorough verification, the diagnosis made by the EMS manager was divided. The final diagnosis of a disease or injury is based on the international classification ICD-10. According to this classification, the patient was divided into a non-traumatic patient, i.e. a person who had a health problem, but no mechanical or thermal force contributed to it. This category includes infectious and parasitic diseases, cancer, diseases of individual systems of the human body, as well as symptoms and features of diseases not classified elsewhere. The second group of this codification includes all injuries and other specific external factors acting on the body causing injury [25].

In the analysis of our own material, in the form of a division of patients under 18 years of age. for the group of trauma patients (n=437) and non-traumatic patients

(n=1221) there was a ratio of N=26% vs. N=74%. These data are identical to those described in retrospective analyzes of EMS activities in patients under 18 years of age. In the study by Shah et al. reports an N=35% ratio of pediatric patients with trauma [28]. In an article on the observation of pediatric patients conducted over 10 years by Oliveira JE Silva et al. it was described that in the age group from 6 to 12 years, trauma constitutes N=35.1% of EMS trips, while in the age group from 13 to 18 years N=32.7% of EMS interventions are for injuries [29]. These studies partially reflect the division of the patient under 18 years of age. per age group in your analysis. In the division into four groups: from birth to 1 year of age. injuries accounted for N=12.41%, aged 1 to 8 years. injuries accounted for N=22.22%, from the age of 8 to 13, injuries accounted for N=35%, and from the age of 13 to 18, injuries accounted for N=28.30% compared to non-traumatic patients. These results are similar to data from studies conducted in our country. In the study by Aftyk et al., based on the example of the Provincial Emergency Service in Lublin, a pediatric patient was divided into two groups and the percentage ratio was shown. In group I from 0 to 9 years of age EMS intervened in injuries N = 22.9%, and in group II from 10 to 19 years of age. this number was N=50.0% [30]. With regard to the Air Medical Rescue Team, the work of Enomoto et al. the results from 2010-2016 were presented, which showed a clear advantage of HEMS intervention in pediatric patients who suffered injuries N = 68.1% [31]. Among trauma patients under 18 years of age male patients predominate. These data are published in studies conducted by Corrado et al. where N=63.8% were boys [32]. Similar results were obtained by Nabeta et al. and Allen et al., who further describe that N=70% of male pediatric trauma patients were admitted to the pediatric hospital [33-34].

Pediatric patients require the same types of medical procedures as adults, but due to their different size and anatomy, many of these procedures are more difficult to perform, and the lack of special pediatric training makes performing medical procedures even more difficult. The role of the EMS is to implement medical procedures at the scene of the incident and during transport to the hospital, and then document them. Each EMS manager is obliged to complete medical documentation during a medical intervention. In Poland, medical documentation completed by the head of the Emergency Medical Services includes MED [24]. The MED should thoroughly describe the elements of the physical examination in the form of a subjective and objective examination. After this description, the EMS manager selects the MCRs that were performed on the patient. Activities to choose from in MED include: suction, self-expanding bag ventilation, insertion of an oropharyngeal tube, endotracheal intubation, connection of a respirator, use of oxygen therapy, performing chest compressions, performing an ECG, performing defibrillation, obtaining intravenous access, applying a cervical collar, using a mattress vacuum, immobilization and application of a dressing. Among the listed activities, several are missing that are within the competences of the EMS manager [35]. In MED, the EMS manager does not have the option of marking the procedure for installing an alternative intubation in the form of a laryngeal mask airway, laryngeal tube or laryngeal tube when opening the airway. In Enomoto et al. In his research, the author indicates that intubation was performed in N = 6.9% of pediatric patients in prehospital care [31]. In a study by Rost et al. the main goal was to identify incorrect positioning of the endotracheal tube in traumatized children, which was inserted by the emergency medical services team. This abnormality amounted to N=26% [36]. Bankole et al. shows that N = 38.2% of children required intubation at the scene of the incident, while a problem occurred during endotracheal intubation in N = 69.2% [37]. In the article by Couret et al. A review of airway clearing methods available to EMS in pre-hospital conditions was performed. The main finding of this review is the serious risk of difficult intubation in the prehospital setting, particularly in pediatric patients. Therefore, each EMS member should be aware of alternatives to endotracheal intubation, such as supraglottic devices, and be able to use them [38].

The indications for peripheral intravenous access are the same as in an adult patient, but pediatric patients require smaller intravenous catheters, and the procedure itself is difficult due to the lack of cooperation of pediatric patients or thin blood vessels. In our study, peripheral vein cannulation was used in N = 13.16%. Enotomo et al. states that during EMS interventions in patients under 18 years of age in N=75.1% intravenous access was used [31]. In the study by Bankole et al. in pre-hospital care, peripheral vein cannulation in pediatric patients was performed in N = 65.7%, while after the arrival of the EMS to the Emergency Department, it turned out that it was to be used in N = 80.4% [37]. Using the example of HEMS interventions in Germany, Helm et al. indicates that in 4-year follow-up in patients under 18 years of age intravenous puncture was used in N = 81.5% of cases [39]. This proves that a large group of pediatric patients transported to hospital require access to the circulatory system through cannulation. In a retrospective analysis, VanderKooy et al. analyzed medical documentation from EMS in children aged 0-18. n=545 patients were included in the study. Intravenous access was attempted in N=27% (n=149), and access was successfully achieved in N=77% (n=111) [40]. Data from VanderKooy et al. are most similar to the material collected in our own research. Unfortunately, a comparison of studies shows that in Poland, emergency medical personnel do not often obtain intravenous access. In patients with severe hypovolemia, peripheral venous access may not be possible, and intraosseous access is an appropriate alternative. In critical situations, if intravenous access fails after three attempts or 90 seconds, intraosseous access should be considered [27]. Intraosseous access is the only alternative in the EMS to peripheral intravenous access. This route has been well validated and is a rapid access route used by emergency medical services

in both adults and children in various health risk states. In an analysis of articles published on Pubmed and Embase from January 1990 to August 2018, Tyler et al. reports N = 95% effectiveness of access using intraosseous puncture [41]. After carrying out the above analyses, it is considered justified to add the option of intubation using supraglottic systems and intraosseous puncture to the option of selecting MEM from MED.

In our study, defibrillation was not used with MEM. Defibrillation is performed at the time of cardiac arrest when a shockable rhythm occurs in the form of ventricular fibrillation or pulseless ventricular tachycardia [42]. This activity has been compared to cardiac massage because it is an activity performed in every cardiac arrest. In studies targeting cardiac arrest in pediatric patients by Nadolna et al., Sahu et al., Banerjee et al. and Matsuyama et al. the number of shockable rhythms occurred N=9.6% - 26% [43, 44, 45, 46].

Ishihara et al. in his epidemiological study compared the outcomes of pediatric patients with severe trauma at the scene of a prehospital incident. He drew attention to the MEM performed before transport to the hospital. These activities included: oxygen therapy N=84.7%, self-inflating bag ventilation N=16.7%, endotracheal intubation N=23.6% and insertion of an oropharyngeal tube N=2.8% [47]. In the data analyzed in our study, these procedures performed in trauma patients were much lower and did not exceed N=1%. For example, the use of oxygen therapy alone in children after injury was performed only N = 0.01%. A major problem with MCR performance was observed here. It should be emphasized that explaining this problem is difficult, but one of the factors is certainly the lack of experience, knowledge and skills.

In the early 1980s, research by Seidel et al. and Ramenofsky et al. showed that up to half of trauma-related deaths in pediatric patients could be prevented. Results in patients under 18 years of age compared to adults with similar degrees of injury tended to be worse. The authors provide several methods to increase the chances of survival in pediatric patients. One of the methods is a thorough examination of the child [48-50].

The State Emergency Medical Services has undergone fundamental changes since the 1990s and has demonstrated improvements in patient care, resulting in increased patient survival rates. Most of these changes and improvements concerned health emergencies in adults, and unfortunately the scale of these advances cannot be fully seen in pediatric patients in emergency medical services. There are still important differences in the care of adults compared to pediatric patients in the prehospital setting. Most publications and research are conducted on adult patients in acute health emergencies. Nevertheless, for some medical staff on duty in the emergency medical services, dealing with a child in a state of sudden health threat is a rare case and there is still a gap between the quality of care for pediatric patients and adults. Basic skills such as physical examination, securing the airway, managing respiratory failure, and obtaining access to a peripheral vein by emergency medical personnel have a higher rate of complications or failures in pediatric patients compared to adult patients. Pediatric pre-hospital care is an important element of the treatment of a child experiencing a health emergency, just as it is in the case of adult health emergencies.

A significant problem of the activities performed by the EMS at the scene of the incident with a patient under 18 years of age. consists in a small number of trainings in the field of pediatric topics related to health threats. In the group of paramedics, this topic constitutes only a small part of the training program, and therefore prehospital care for pediatric patients may not be performed or is not performed at the same level as pre-hospital care for adults in states of sudden health threat.

CONCLUSIONS

Patient under 18 years of age is a problem for the Emergency Medical Team due to a very small group of interventions, which is related to the lack of experience in performing examinations and implementing medical rescue activities. The main reasons for the intervention of Emergency Medical Teams in pediatric patients are diseases in each age group.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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ORIGINAL ARTICLE

Assessment of the activity of Trauma Centers for Children in Poland in 2021

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ABSTRACT

Aim: Injuries are dominant causes of death and hospitalization among children and adolescents. In some countries, there are designated pediatric trauma centers (PTCs) that offer multiple levels of care for trauma patients. Our aim is to demonstrate that the criteria in Polish PTCs may not identify a large group of patients with life-threatening conditions, and they may be referred to centers with lower capabilities.

Material and methods: We analyzed all trauma patients transported by ambulance to the Emergency Department in Pediatric Teaching Hospital of University Clinical Center of the Medical University of Warsaw in 2021.

Results: Out of 981 pediatric trauma patients, 27 qualified for PTC. Key factors determining which children are more likely to qualify for PTC include the influence of alcohol, falls from heights, the need for analgesics, and fluid therapy. Physical examination abnormalities more likely found among patients qualified for PTC were: GCS≤13, abnormal pupillary reaction, abnormal pupil width, seizures, a decrease in systolic blood pressure, abnormal heart rate, and a decrease in oxygen saturation. There is a significant group of patients who do not meet PTC criteria but present a risk to life or health.

Conclusions: Only a small number of admitted children met the qualification criteria for PTC. It seems that we should not assess a patient solely based on pre-established criteria, but the universality of this problem requires the creation of a segregation system that would allow access to patients more individually.

KEY WORDS

trauma centers, emergency treatment, pediatric emergency medicine, Emergency Departments, wounds and injuries, emergency medical services

INTRODUCTION

All over the world the dominating causes of death among children and adolescents are external causes like injuries and poisoning [1, 2]. For children aged 1 to 19 injuries caused 56% of deaths in 2013 [2]. They are also the most common reason for hospitalization in pediatric wards [3].

Many countries undertake various actions to prevent mortality caused by injuries among children and adolescents [4, 5]. For example, in some countries there are designated trauma centers which are multi-specialty hospitals that offer multiple levels of care for trauma patients. Dedicated trauma service care has been reported to improve outcomes in Canada, England, Australia and in the US [6-11]. There is compelling evidence from the US that access to specialized trauma centers reduces post-traumatic mortality by approximately 15% to even 25% [12-14].

Pediatric trauma center (PTC) is a part of the hospital, where patients under 18 years of age with serious injuries can be quickly diagnosed and treated, they have access to specialized diagnostics, efficient communication with emergency medical services, access to the Intensive Care Unit and qualified staff [13, 15]. In Poland, they were founded in 2017 and according to data from the National Health Fund, there are currently 11 Pediatric trauma centers (PTCs) [3].

According to the regulation of the Minister of Health in Poland, a patient under the age of 18 is qualified for trauma centers treatment only if he or she meets certain criteria, criteria were shown in Table 1 [15].

Many pediatric patients meet anatomical criteria but do not meet the physiological criteria, which makes them not qualified for the treatment in trauma centers.

During the analysis of the number of patients eligible for the treatment in the trauma center and a small number of patients meeting the qualification criteria and at the same time requiring surgical interventions, the validity of Polish qualification criteria may raise doubts [16].

AIMS

In this paper, we analyzed patients from the Trauma Center operating under the Emergency Department in Pediatric Teaching Hospital of University Clinical Center of the Medical University of Warsaw in 2021. Our aim is to prove that criteria in Poland may not identify a large group of patients with severe and life-threatening conditions, and they may be referred to the centers with lower

Table 1. Pediatric Trauma Center Admission Criteria.

A patient under the age of 18 qualifies for admission to a PTC if the injury meets at least one of the following anatomical criteria and at least two of the following physiologic parameters:
Anatomical Criteria
1. Penetrating wound to the head or torso or blunt trauma with evidence of internal organ injury to the head, chest, or abdomen. 2. Amputation of a limb above the wrist or ankle joint. 3. Extensive crush injury to an extremity. 4. Spinal cord injury. 5. Unstable chest wall. 6. Fracture of an extremity with vascular or nerve injury. 7. Fracture of two or more proximal long bones of the extremities or pelvis.
Physiologic Parameters (Table 2.)
1. Systolic blood pressure falls below the age-specific threshold. 2. Heart rate deviates outside the age-specific range. 3. Respiratory rate deviates outside the age-specific range. 4. Glasgow Coma Scale (GCS) or Pediatric Coma Scale (PCS) score for children under 3 years of age is 13 or less. 5. Arterial blood oxygen saturation is 90% or less.
Individuals under the age of 18 who experience a sudden medical emergency are eligible for treatment at the center, including in the following circumstances despite the absence of visible anatomical criteria and significant abnormalities in physiological parameters observed at the scene:
Additional Criteria
1. Multisystem trauma or death of another person in the same event. 2. Ejection from a motor vehicle, entrapment, or fall from a height greater than 3 meters. 3. Extrication time from a vehicle, collapse, or debris field exceeds 20 minutes, despite the absence of visible anatomical injuries and significant physiologic derangements on scene.

Table 2. Physiological parameters values.

1. Minimum systolic blood pressure values based on the child's age		
No.	**Child's age**	**Systolic blood pressure**
1	1	65
2	2-5	70
3	6-12	80
4	>12	90
2. Heart rate range based on child's age		
No.	**Child's age**	**Heart rate**
1	1	110-150
2	2-5	90-130
3	6-12	70-110
4	>12	60-100
3. Respiratory rate range based on child's age		
No.	**Child's age**	**Respiratory rate/min**
1	1	30-40
2	2-5	20-30
3	6-12	15-25
4	>12	12-20

Table 3. Gender distribution of qPTC and nqPTC patients.

Sex	All children	qPTC	nqPTC
Female	412 (42%)	9 (33.33%)	403 (42.24%)
Male	569 (58%)	18 (66.67%)	552 (57.76%)
Total	**981**	**27**	**954**

Table 4. Age distribution of qPTC patients.

NFZ Group	Age	All children	qPTC	nqPTC
I	0-1	158 (16.1%)	4 (14.81%)	154 (16.14%)
II	2-5	216 (22.0%)	4 (14.81%)	212 (22.22%)
III	6-12	296 (30.2%)	8 (29.63%)	288 (30.19%)
IV	>12	311 (31.7%)	11 (40.74%)	300 (31.45%)
Total		**981**	**27 (2.75%)**	**954 (97.25%)**

reference than trauma centers. We believe that it is necessary to improve the collection of data about patients in PTCs, which would enable drawing conclusions and improving the functioning of trauma centers. However, due to the small number of patients admitted to PTCs in Poland it is also difficult to draw specific conclusions regarding the operation of PTCs [16]. Our results may encourage government, non-government agencies and healthcare providers to involve and refine the pediatric trauma system in Poland.

MATERIAL AND METHODS

This study embraces a retrospective analysis of medical documentation from patients transported by ambulances to the Emergency Department (ED) of the Pediatric Teaching Hospital in Warsaw, where Pediatric Trauma Center (PTC) is located. The patients originated from the whole area of the operation of PTC. The scope of the PTC operation reaches even 130 kilometers. Data for the study were collected from January 1st, 2021, to December 31st, 2021. In order to participate in the study, patients must meet the following criteria: they must be under 18 years old, have sustained an injury or be suspected of having one, and have been transported to the Emergency Department (ED) by Emergency Medical Services (EMS). 981 patients passed the access criteria and were included in the study. Each patient was analysed in respect of age, sex, location of the event, mechanism of trauma, presence of alcohol or recreational drugs, suspicion of suicide, localization and character of trauma, vital signs, signs and symptoms, pain scale, administered treatment and procedures, and GCS score. Not all of the 981 patients met the criteria for admission to the Pediatric Trauma Center. The study analyzed not only the patients admitted to the PTC (qualification for PTC - qPTC) but also those not meeting the criteria (non-qualification to PTC - nqPTC) and cases where the mechanism of trauma, abnormal vital signs, or degree of trauma suggested a risk of life or health (severe cases non-qualification for PTC - snqPTC). Patients have been selected to the snqPTC group by a screening process performed by the research team with criteria such as: abnormal vital signs and symptoms suggesting serious trauma, performed procedures by paramedics on site suggesting serious trauma and mechanism of incidents suggesting serious trauma. All patients from nqPTC group were screened and later reviewed by another researcher before inclusion to snqPTC group. Those cases were subjected to additional analysis including the duration of hospitalization, occurrence of operations, admission to the intensive care unit, and the occurrence of permanent impairment due to trauma. The acquired data were used to create a database, which was then subjected to subsequent statistical analyses. These analyses compared patients meeting PTC admission criteria (qPTC) to patients not meeting PTC (nqPTC). Additional analyses compared patients meeting PTC criteria (qPTC) to cases with a risk of life or health (snqPTC). The analysis was conducted in the STATISTICA software. Differences between qualitative variables were tested using the Maximum Likelihood Chi-square test, and between quantitative variables using the Mann–Whitney U test. The significance level was set at 0.05. The source of data were provided by the Emergency Department in Pediatric Teaching Clinical Hospital University Clinical Center of the Medical University of Warsaw. The approval for access to patients documentation and publication has been received from the hospital's director. Ethics committee approval was received for this study from the Ethics Committee of the Medical University of Warsaw – decision number AKBE/80/2022. Following the Helsinki Declaration, the study was fully anonymized, ensuring no data could be used to identify the patients.

Table 5. Distribution of injured area.

Injured area	Injured patients	Injured qPTC patients
Head	591 (60.24%)	19 (70.37%)
Neck	37 (3.77%)	2 (7.41%)
Chest	76 (7.75%),	4 (5.26%)
Abdomen	36 (3.67%),	2 (5.56%)
Pelvis	24 (2.45%),	0 (0.00%)
Upper limb	228 (23.24%),	7 (3.07%)
Lower limb	177 (18.04%),	9 (33.3%)

Table 6. Distribution of fulfilled psychological criteria of nqPC and qPTC patients.

Number of fulfilled physiological criteria	nqPTC	qPTC
0	540 (56.6%)	11 (40.74%)
1	364 (38.16%)	6 (22.22%)
2	46 (4.82%)	5 (28.52%)
3	4 (0.42%)	2 (7.41%)
4	0	2 (7.41%)
5	0	1 (3.70%)

Table 7. Distribution of symptoms in qPTC and snqPTC patients.

	Symptoms in patients qPTC (N=24)	Symptoms in snqPTC patients (N=140)
Dyspnoea	3 (12,5%)	1 (0,71%)
Shock	1 (4,17%)	3 (2,14%)
Meningeal symptoms	1 (4,17%)	2 (1,43%)
Seizures	5 (18.52%)	22 (2.31%)
Vomiting	1 (4,17%)	60 (42,86%)
Abnormal or no reaction of the pupils to light	3 (12,5%)	10 (7,14%)
Abnormal pupillary width	5 (20,83%)	16 (11,43%)

RESULTS

In the study, we analyzed 981 pediatric trauma patients who were brought to the Emergency Department (ED) by Emergency Medical Services (EMS) between January and December 2021. Of these, 27 were qualified for PTC (qPTC). The gender distribution of all patients was as follows: 412 (42%) females and 569 (58%) males.

To present the age distribution of qPTC, we used the age division of children proposed by the Polish National Health Fund (NFZ). It consists of 4 age groups, whose distribution is presented in Table 4. The largest subgroup prone to injuries was Group IV, which includes children aged over 12 years and comprises 311 (31.7%) patients. The distribution of children among age groups covered by the NFZ did not significantly differ between patients qualifying for PTC (qPTC) and those who did not (nqPTC).

Among the surveyed group of patients, the most common injury was head trauma, affecting 591 patients (60.24%), with 19 (70.37%) of those qualifying for PTC (qPTC). The rest of analyzed injuries is presented in table 5. None of the aforementioned injuries showed significant statistical correlation with PTC qualification.

Table 8. Distribution of facts and key events about further hospitalization in qPTC and snqPTC patients.

	Patients qualified for PTC (N=24)	Patients who do not meet PTC criteria but present risk of life or health (N=140)
Patients undergoing surgery	10 (41,67%)	11 (7,86%)
Patients admitted to the Intensive Care Unit	2 (8,33%)	2 (1,43%)
Average hospitalization time at Intensive Care Unit	5	3,5
Patients hospitalized for at least a day	18 (75%)	42 (30%)
Average hospitalization time at unit different than Intensive Care Unit	24,45	5,48
Patients with permanent health damage	6 (25%)	1 (0,71%)
Number of deaths	1 (4,17%)	no data

The majority of injuries occurred at home (439, 44.75%) and in public places (280, 28.54%). The distribution of injury locations did not correlate with the qualification of patients for PTC.

In cases of motor vehicle accidents involving 121 patients, 8 (6.61%) qualified for PTC. There was a correlation between PTC qualification and injuries resulting from motor vehicle accidents (OR=3.130, 95%CI [1.34, 7.32], p=0.0153).

There were 5 patients suspected of substance abuse, but none of them qualified for PTC. Children under the influence of alcohol were more likely to qualify for PTC (OR=5.060, 95%CI [1.42, 18.01], p=0.0348). Among 26 children suspected of alcohol influence, 3 (11.54%) were qualified for PTC.

Falls from height, affecting 185 patients, correlated with PTC qualification, as 13 (7.03%) of the children qualified for PTC (OR=4.22, 95%CI [1.95, 9.14], p=0.00046).

Suspicion of suicide attempt did not correlate with injury severity and PTC qualification (OR=0.953, 95%CI [0.13, 7.22], p=0.96300). Only one out of 38 individuals qualified for PTC.

Analgesics were administered to 205 (20.9%) patients. Higher percentage of patients, who received analgesics belonged to the qPTC group, at 48.15% (13 patients). In the nqPTC group, the percentage was 20.13% (192 patients) (OR=3.685, 95%CI [1.70, 7.97], p=0.00139).

QPTC PATIENTS

Among qPTC patients, a statistically higher proportion (9 patients, 33.3%) received fluid therapy (OR=8.173, 95%CI [3.51, 19.03], p=0.00002). An increased diameter of the pupil was found to be a factor in predicting qualification for PTC. In the group of patients qPTC, 7% (2 patients) exhibited abnormal pupillary reaction to light, whereas in the nqPTC group, it was only 1% (10 patients) (OR=7.552, 95%CI [1.57, 36.27], p=0.03982). A similar correlation was observed when assessing the width of pupils; 11% (3 patients) of the qPTC group and 2% (16 patients) of the nqPTC group had abnormal pupil width (OR=6.89, 95%CI [1.89, 25.09], p=0.01 569).

Seizures were a common feature of injuries suffered by qPTC patients, occurring in 18.52% (5 patients), compared to 2.31% (22 patients) in the nqPTC group (OR=9.628, 95%CI [3.34, 27.76], p=0.00052). Bleeding was experienced by 25.93% (7 patients) in the qPTC group and 17.82% (170 patients) in the nqPTC group (OR=1.603, 95%CI [0.67, 3.85], p=0.28739). Vomiting occurred in 6.22% (61) of all patients, and only 1 (3.70%) of them was qPTC, which indicates a lack of correlation (OR=0.573, 95%CI [0.76, 4.30], p=0.58325).

We established that qPTC patients required immobilization (OR=3.731, 95%CI=[0.12, 0.60], p=0.00060), distal venous line (OR=3.168, 95%CI=[1.47, 6.84], p=0.00200), cervical collar (OR=5.525, 95%CI=[0.07, 0.47], p=0.00009) and long spine board (OR=7.519, 95%CI=[0.05, 0.35], p=0.00000) more often than non-qPTC patients.

Patients qPTC did not required ECG (OR=4.435, 95%CI=[1.46, 13.49], p=0.00423), dressing (OR=3.045, 95%CI=[0.91, 10.20], p=0.057) and nonpharmacologic procedures (OR=2.316, 95%CI=[0.87, 6.17], p=0.08423) more frequently than other snqPTC.

CRITERIA

The number of patients and the number of physiological criteria they fulfilled are presented in table 6. Significantly, qPTC patients were more likely to fulfill more than 2 (OR=10.635, 95%CI [4.63, 24.42], p=0.00000) and more than 3 (OR=53.977, 95%CI [13.57, 214.78], p=0.00000) physiological criteria than nqPTC patients.

Regarding anatomical criteria, 7 patients suffered a penetrating wound to the head or torso, or blunt trauma with symptoms of damage to internal organs of the head, chest or abdomen. There were no patients meeting other anatomical criteria.

The number of qPTC patients according to additional criteria was 18, which includes the 17 of qPTC patients with the additional criterion of falling out of a vehicle, falling or being hit. The number of qPTC patients with the criterion of additional multi-organ injury or death in the same accident of another person was 2.

The evaluation of patients on the Glasgow Coma Scale (GCS) appears to be a good prognostic factor for qPTC, as 33.3% (9 out of 18) of qPTC patients had a GCS lower than or equal to 13 (OR=22.214, 95%CI=[8.95, 55.16], p<0.00001).

A decrease in systolic blood pressure was observed more frequently in qPTC (2 patients, 7.41%) than in nqPTC (3 patients, 0.31%) (OR=25.360, 95%CI=[4.06, 158.52], p=0.00482). Unfortunately, blood pressure measurement was obtained only in 65.95% (941) of all patients.

Abnormal heart rate was also more common in qPTC (12 patients, 44.4%) than in nqPTC (173 patients, 18.13%) (OR=3.612, 95%CI=[1.66, 7.85], p=0.00201). There is a correlation between patient qualification for PTC and a decrease in oxygen saturation, observed in 14.81% (4) of qPTC patients and 0.63% (6) of nqPTC patients (OR=27.478, 95%CI=[7.26, 104.01], p=0.00006). However, no correlation was found between abnormal respiratory rate (271 patients) and the likelihood of qualifying for PTC (8 patients) (Table 7).

In the study, findings revealed that among the participants: 3 (12,5%) patients from qPTC group and 1 (0,71%) from nqPTC group experienced dyspnea, 1 (4,17%) patient from qPTC presented with shock, while in nqPTC group it was 3 (2,14%) patients. Additionally, 1 (4,17%) qPTC patient and 2 (1,43%) nqPTC patients exhibited meningeal symptoms, 5 (18.52%) patients in qPTC group, and 22 (2.31%) patients in nqPTC group manifested seizures. 1 (4,17%) one patient from qPTC and 60 (42,86%) from nqPTC group reported vomiting. Abnormal or no reaction of the pupil to light was observed in 3 (12,5%) patients in qPTC group and 10 (7,14%) in nqPTC group. 5 (20,83%) patients in qPTC group and 16 (11,43%) in nqPTC group demonstrated abnormal pupillary width.

SNQPTC PATIENTS

140 patients, who do not meet PTC criteria but present a risk of life or health (snqPTC), have been compared with qPTC patients. We established that qPTC patients were more often subjected to surgery than snqPTC patients (OR=8.442, 95%CI=[3.05, 23.37], p=0.00007), but the number of patients undergoing surgery was higher among the group of snqPTC. The operation was performed in 10 (41.67%) of qPTC patients and 11 (7.86%) of snqPTC patients. Patients qPTC did not undergo hospitalization in the Intensive Care Unit more frequently than other snqPTC (p=0.8872). In both groups there were 2 (8.33% of qPTC and 1.43% of snqPTC) patients who required treatment in the Intensive Care Unit. The median hospitalization time for qPTC patients (Me=8.5 ,Q1=5, Q2=31) was similar for snqPTC patients (5 days) and qPTC patients (3,5 days) (Me=4, Q1=1, Q2=7) (p=0.003414). 42 (30%) of patients from the snqPTC group were hospitalized for at least a day, while in the qPTC group it was 18 (75%) patients. Average hospitalization time at units different than Intensive Care Unit were 24,45 days for qPTC patients and 5,48 for snqPTC patients. 6 (25%) patients from the qPTC group and 1 (0,71%) patient from the snqPTC group suffered permanent health damage. There were 1 (4,71%) deaths in the qPTC group, no data for deaths among snqPTC group (Table 8).

DISCUSSION

Injuries are the number one cause of deaths among children, that is why proper trauma system organization is crucial [1]. Appropriate equipment, transportation, and trained staff are essential for the success of trauma systems [17]. It can significantly reduce disability and prevent deaths [14,18,19,20]. Our study was conducted to determine that criteria in Poland may not identify a large group of patients with severe and life-threatening conditions. Poland is not the only country dealing with these issues, other countries also face problems with the PTC system. It can negatively affect a pediatric trauma patient's outcome.

CRITICAL PROCEDURES PERFORMED IN PTC

Pediatric trauma centers perform diagnostic and therapeutic procedures that often save the lives of children who have experienced serious injuries. The most common procedures are endotracheal intubation and central venous catheterization. Also other procedures, such as: intraosseous line placement, pharmacologic cardioversion, tube thoracostomy, needle thoracostomy, electro cardioversion, defibrillation, and pericardiocentesis are sometimes performed [21, 22].

PERMANENT ACCESS TO PROFESSIONAL FACILITIES

It is clear that the proper treatment of trauma patients should be conducted in a place equipped with professional facilities. Israeli highly experienced policy makers, senior nursing managers, and medical managers in pediatrics and trauma emphasize that the most appropriate Emergency Department for treating pediatric trauma is the one that can provide the best possible response to the needs of the children. It should be equipped with the necessary infrastructure, including the proximity of operating rooms, laboratories, a blood bank, an imaging system, and a CT unit. This is in accordance with previous reports that also emphasized the need for dedicated equipment and drug treatment [23].

PTC ORGANIZATION IN OTHER COUNTRIES

In contrast to adults, the situation regarding pediatric trauma care from an international perspective and

the global management of severely injured children remain rather unclear [24]. As it turns out, the problem concerns not only developing countries but also highly developed ones. 75% of PTCs in France have internal protocols for pediatric trauma patient care. Despite this, no national guidelines on the organization of care for pediatric trauma patients in France have been developed yet. Because of this heterogeneity some patients are admitted in improper departments including the adult emergency department or the intensive care unit. In some trauma centers children could be managed by non-pediatricians [25]. Similar problems occur even in one of the most developed countries in the world, Switzerland. The absence of a national pediatric trauma database is noted. Major trauma presentations only constitute a small proportion of the total patient load in the pediatric emergency department, and trauma team activation does not necessarily correlate with injury severity [26]. In developing countries like Brazil, trauma protocols, such as those developed by the Advanced Trauma Life Support course, are widely taught. However, few studies have assessed the extent to which the use of protocolized trauma assessment improves outcomes. Clinicians observe an urgent need to organize pediatric trauma systems through enhanced triage and provider training [27]. The other developing country without an organized trauma system is Turkey. The overall mortality rate in the PTC in Turkey was 8,8%, whereas in the US which has an organized trauma system, it was 4,7% [28]. The system that accepts too many non-severe cases also fails to meet the criteria for well-organized trauma centers. The United States faces this problem. Many minimally injured patients do not require treatment at a higher level trauma center. For example, in one study the number of such patients was as much as 43.7%, while in another it was 39% or 22.4% in the next one [29-32]. What is more, in one study the appropriateness of transport by helicopter emergency medical services (HEMS) was assessed. It has been proven that in almost two thirds cases helicopter transport was not necessary [33]. The examples discussed above illustrate the importance of a well-balanced and properly defined trauma center system with elaborated criteria.

THE PROPER DISTRIBUTION OF PTCS

A retrospective analysis of data from the Trauma Registry between October 2015 - September 2020 in the Appalachian health system (the US) examined the effects of adding another pediatric trauma center near an existing pediatric trauma center. Four years of data showed that although there has been a decline of the number of patients in an existing pediatric trauma center, there were no differences in outcomes, complications, and mortality when a second PTC was added [34]. The data from the US also shows that the existence of PTC is important because young children have better survival at PTCs compared to Adult Trauma Centers (ATCs) [35]. For adolescents there is no difference in mortality between ATCs and PTCs [35-38]. That suggests that survival benefit in PTC is age dependent.

POLISH PTCS ISSUES

Considering the concepts of the structure and organization of pediatric trauma centers worldwide, it is valuable to examine the current state of PTCs in Poland. Polish scientific literature postulated the establishment of trauma centers for children [39]. This culminated in the establishment of PTCs in 2016. Since then, the regulations have been amended twice, with admission criteria remaining unchanged [15]. It should also be remembered that Polish hospitals and emergency departments have problems with meeting the requirements imposed by state regulations [40]. Furthermore, admission criteria for adults and children differ significantly, with pediatric criteria being more comprehensive. In Warsaw in 2021, out of 981 pediatric trauma patients, only 27 were qualified for PTC. It should be mentioned that from the group of unqualified patients, a significant number also required a surgical procedure, and their hospital stay was long. It is important to remember that each patient should be treated individually. It seems that we should not assess a patient solely based on pre-established criteria, and in some situations, the evaluation of the medical team should be sufficient to admit pediatric trauma patients to PTC. It is concerning that, in some cases, pre-established, very extensive criteria seem to prevent patients from receiving the most proper medical care. On the other hand, we noticed that some patients admitted to PTC didn't require assistance at such a high-level facility and could be transferred to lower-referenced hospitals.

The other issue seems to be the lack of a national data collection system. The evaluation of the functionality, effectiveness, and eventually, the profitability of Polish centers is almost impossible to conduct, and the negative impact of such a lack on patient care has also been highlighted in other research papers published. Another important concern we would like to discuss is the size of the zones that are outside the reachable distance from the Trauma Centers. It has been suggested that trauma patients benefit greatly from being treated in PTCs, rather than in smaller centers, but such analysis could give us a useful indication of whether it would be better to transport the patients to the nearest emergency department or to take the time for their transportation to the trauma center.

All things considered, we have concluded that there are no collective registers for pediatric trauma patients in Poland, and no one monitors the number of patients, their condition, and the results of short-term and long-term care [41]. It would be helpful if we could carry out such a detailed analysis for all 11 pediatric trauma centers operating in Poland [16].

CONCLUSIONS

The study shows that the most common reason for calling the Emergency Medical Team in 2021 among

trauma patients was a head injury, mainly in boys aged more than 12 years old. The accidents most frequently occurred at home and public places.

The patients who most often qualified for the Pediatric Trauma Center were children who had suffered injuries during a fall from height. There was also a positive correlation between injuries caused by road traffic accidents and fulfilling criteria of admission to the PTC. The most accurate reflection of the patient's condition turned out to be the GCS and saturation assessment. Among the remaining elements of the physiological criteria, decreased blood pressure and abnormal heart rate were more common in patients qualified for PTC than those not qualified for PTC. However, there was no relationship between abnormal respiratory rate and admission to PTC. qPTC patients more frequently fulfilled more than two physiological criteria. From the anatomical criteria, only penetrating wounds to the head or torso, or blunt trauma with symptoms of damage to internal organs of the head, chest or abdomen was met. More than a half of the patients were qualified to the PTC by fulfilling the additional criteria, related to multi-organ injury or death. An abnormal reaction to light, an episode of seizures and bleeding turned out to be symptoms that we observe more often among patients qualifying for PTC. Fluid therapy and analgesic treatment was needed among a higher percentage of patients meeting criteria for PTC than not. qPTC patients more often require surgery, and the average time of hospitalization in units other than the Intensive Care Unit was longer for them compared to snqPTC patients. It's crucial to mention that a significant number of nqPTC patients also underwent surgery, required treatment in the Intensive Care Unit, and the median hospitalization time was similar to that of the qPTC group.

The traumatic nature of an accident is not always reflected in the qualification criteria for the Pediatric Trauma Center. It is important to remember that each patient should be treated individually and his or her condition ought to be assessed and monitored regularly. However, the universality of this problem requires the creation of paths that would allow for the efficient segregation of patients requiring multidisciplinary care, which they can find in Pediatric Trauma Center.

Improving the qualification criteria for such centers would shorten the time needed to receive help and, as a result, lead to better treatment outcomes. Additionally, this procedure would reduce the number of patients admitted to PTC whose injuries are inadequate to the care provided. Redirecting these patients to centers with lower reference levels would leave places vacant for the most severely injured trauma patients.

LIMITATIONS

We recognize certain limitations of our study. First of all, we have analyzed only pediatric patients transported by EMS to ED of the Pediatric Teaching Hospital of the University Clinical Center of the Medical University of Warsaw in 2021. What is more, our paper includes patients from Warsaw and the surrounding area, it does not include patients from other parts of Poland. We did not mention patients transferred by private transport. We may lack findings that could have been seen in larger cohorts.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest.

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REVIEW ARTICLE

Artificial intelligence in ECG analysis - future or present?

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ABSTRACT

This review discusses the significance of Electrocardiography (ECG) as a fundamental diagnostic tool for identifying electrical abnormalities in the heart. Despite its inception a century ago, ECG remains the gold standard for cardiovascular assessment. ECGs are routinely conducted in various healthcare settings, from family physician offices to emergency rooms, underscoring its ubiquitous clinical utility. However, misinterpretation of ECGs can lead to detrimental treatment decisions, emphasizing the critical need for accurate analysis. In recent years, artificial intelligence (AI) has emerged as a promising tool for ECG interpretation. AI models, designed to replicate human cognitive functions, undergo training with extensive datasets. While AI shows potential in improving ECG interpretation quality, it is not without limitations. Physician expertise remains indispensable in interpreting ECG findings accurately. Despite its potential, AI's clinical application in ECG interpretation has yet to gain widespread approval. The paper emphasizes the importance of understanding the limitations and risks associated with AI implementation in cardiovascular diagnostics.

KEY WORDS

artificial intelligence, electrocardiography, new technologies

INTRODUCTION

ECG is a common test used in the non-invasive diagnosis of electrical disorders of the heart [1]. In 1924, a Nobel Prize was awarded for the discovery of the mechanism for recording the electrocardiogram, even though this happened 100 years ago the ECG is still the gold standard today [2]. ECGs are performed in family doctor's offices, ambulances, emergency rooms, wherever the patient has first contact with health care [3]. Misinterpretation of the electrocardiogram can result in adverse management decisions, with negative consequences for the patient's health [4]. Artificial intelligence are computational algorithms that have been created to mimic human cognitive functions. Artificial intelligence models are trained by providing them with massive amounts of data [5].

The quality of ECG interpretation has been steadily improving over the past few years; unfortunately, it is not perfect and has its limitations, and physician experience in evaluating the electrocardiogram is still required [6, 7].

THE AIM

The following review aims to present the potential use of AI in ECG interpretation and the limitations and dangers of the above technology. The paper shows why the use of AI in ECG interpretation has not been approved for clinical use to date.

REVIEW

LIMITATIONS AND CHALLENGES

Machine learning methods are prone to errors, with overfitting being a prominent example. Overfitting occurs when there is an imbalance between the number of features and the amount of data in the training set [8], leading the algorithm to perform well on the training data but poorly on unseen data, indicating poor generalization. While traditional statistical approaches may excel with smaller datasets, machine learning harnesses substantial computational power to efficiently classify vast amounts of data. Certain machine learning techniques can be opaque, making it difficult to discern how conclusions are reached-an issue often referred to as the "black box" nature of machine learning [9]. This lack of transparency can undermine clinicians' confidence in employing machine learning-based technologies for active clinical decision-making. Establishing regulatory frameworks for these accurate yet non-transparent machine learning methods presents a significant challenge. As AI is fundamentally a data-driven discipline, the quality of the data used to train and validate machine learning algorithms is paramount [10]. Collaboration and data sharing among research institutions are crucial for amassing substantial, reliable datasets to enhance the generalizability of machine learning approaches. However, this underscores the challenge of maintaining data security and privacy,

necessitating greater transparency and stricter adherence to data management regulations. The growing integration of machine learning algorithms into clinical decision-making processes is poised to raise questions regarding individual responsibility and physicians' fiduciary duty to patients [11, 12]. Regulatory guidelines will be essential to clarify the allocation of liability in cases of AI-aided technology failures. In the realm of cardiology, practitioners are likely to prefer AI-assisted rather than AI-driven decision-making in the foreseeable future [13]. According to a study by Anthony H. Kashou MD, cardiologists are able to evaluate 12-lead ECGs with 69.3% accuracy [14].

ARTIFACTS

Artifacts of ECG recordings are a known cause of lowering the diagnostic value of the test performed.

In order to increase the efficiency of AI in ECG analysis, it is extremely important to perform the test properly standardized, to prepare the patient properly, and to correct the placement of electrodes if necessary [15]. Personnel performing the test should also be trained to immediately notify the physician when the automated ECG evaluation detects abnormalities [16].

MYOCARDIAL INFARCTION

Acute myocardial infarction (MI), the classic "heart attack," is caused by the sudden loss of blood flow and oxygenation to the heart muscle due to complete occlusion of a coronary artery. The risk factors, clinical presentation, and serial changes in ECG and serologic markers as myocardium is damaged are well known [17].

ECG changes that accompany the first 10-15 minutes of acute full-thickness myocardial ischemia in leads whose secondary poles face the ischemic area include ST-segment elevation and T-wave inversion [18].

ECG is the cornerstone in the diagnosis of ST-segment elevations present in myocardial infarctions (STEMI) [19].

Improper ECG evaluation can delay the diagnosis of a life-threatening condition and increase the time to the coronary angiography lab [20]. Automated systems present varying efficacy in this disease entity. False-positive results(overdiagnosis) in 0 to 42% and false-negative results in 22 to 42% [21]. Bosson et al. showed in their work that the results of automated interpretation are more likely when numerous artifacts are eliminated when the medical staff performs the test [22]. Because of its low diagnostic value, automated ECG analysis in acute coronary syndromes is not currently recommended [21].

To improve the diagnostic value of automated ECG analysis Recording additional right-sided precordial leads should also be suggested in inferoposterior infarctions to make the distinction between a right or circumflex coronary artery occlusion [19]. Analyzers should also look at the patient's gender, age, race and previous ECGs in their algorithm. All of these variables underlie the diagnosis of acute coronary syndromes and MI [19-21].

ATRIAL FIBRILLATION

Atrial fibrillation (AF) is the most common heart rhythm disorder. It is seen mostly in the elderly but even young people who do not have underlying heart disease may suffer from it. Although AF itself is usually not lethal, it increases the risk of AF-related complications like heart failure and thromboembolism, which lead to increased morbidity and mortality [23].

Manual ECG screening for AF is time-consuming and error-prone, so studies have been decided on systems that use artificial intelligence to both predict the onset of AF and detect an episode of this tachyarrhythmia at a given time based on the electrocardiogram [24, 25].

Zachi I Attia et al. published a study in 2019 in which they described, based on other work, that interatrial block (Bayés syndrome) is associated with both AF and stroke risk. In addition, nearly one-third of AF patients undergoing cardioversion had extra-atrial contraction of the left atrial appendage despite sinus rhythm visible on the ECG. Taking all these observations into account, the authors developed an AI-enabled electrocardiograph using a neural network to detect AF during normal sinus rhythm using a standard 12-lead ECG. They used data collected from 180,922 patients comprising 649,931 normal sinus ECG recordings.

After more than a month of training the AI model, it was able to recognize atrial fibrillation with a sensitivity of 82.3% (80.9-83.6) and specificity of 83.4% (83.0-83.8) with an overall accuracy of 83.3% (83.0-83.7) [24].

Erdong Chen et al. investigated the use of wristband AF compared to a 12-lead ECG evaluated by a physician. 401 subjects were included in the study group. Each person had a 12-lead ECG described by a senior physician and then the wristband was used in a quiet environment for 3 minutes. The results of the study were considered satisfactory, receiving a sensitivity of 80.00% (72.52-85.90) and specificity of 96.81%(93.58 - 98.51) with an overall accuracy of 90.52%. Compared to the 12-lead test described by the doctor where the sensitivity was 96.67%, specificity 98.01% with an accuracy of 97.51% [26].

LEFT ATRIAL HYPERTROPHY

Over the past few years, various simple criteria for diagnosing left atrial hypertrophy on ECG have been used. More recently, more complex criteria have been developed taking into account QRS duration, QRS area, age, gender, race, anatomical conditions. Automated ECG analysis could facilitate diagnosis by analyzing all these criteria simultaneously [27].

BRUGADA SYNDROME

Brugada syndrome (BrS) is an inherited cardiac disorder, characterized by a typical ECG pattern and an

increased risk of arrhythmias and sudden cardiac death. BrS is a challenging entity, in regard to diagnosis as well as arrhythmia risk prediction and management. Nowadays, asymptomatic patients represent the majority of newly diagnosed patients with BrS, and its incidence is expected to rise due to (genetic) family screening [28].

Robert Ronan et al. in their study used 3,500,000 ECG studies of NYU patients to train AI using VICReg (Variance-Invariance-Covariance Regularization. While conducting only 200 BrS ECG studies. The AI training resulted in a model capable of detecting BrS with a sensitivity and specificity of 87% based on the ECG [29].

ANEMIA

Anemia, characterized by a decrease in hemoglobin concentration, stands as the most prevalent hematological condition, impacting over 2 billion individuals worldwide (30). Its etiology can vary, stemming from both acute and chronic ailments, including gastrointestinal bleeding, malnutrition, malignancy, and chronic kidney disease. While some causes of anemia can be effectively managed with straightforward treatments, others, like thalassemia, demand regular monitoring. Certain acute causes, such as significant gastrointestinal bleeding, pose life-threatening risks and necessitate prompt identification [31]. Joon-Myoung Kwon and colleagues conducted a retrospective, multicenter study on a deep learning algorithm for detecting anemia using ECGs. Training data comprised 57,435 ECG recordings, with internal validation on 7,974 ECGs and external validation on 4,665 ECGs from a different hospital. Three types of deep learning models were developed: for 12-lead ECGs, AUROC was 0.923 for internal validation and 0.901 for external validation; for 6-lead ECGs and lead I, AUROC ranged from 0.841 to 0.890. In each case, the algorithm aimed to detect hemoglobin concentrations ≤10g/dl. The results indicate that the algorithm efficiently and accurately detected anemia. The application of artificial intelligence could potentially be used for screening for anemia based on ECGs in the future [32].

DISCUSSION

Currently, the use of AI-based ECG evaluation algorithms is limited almost exclusively to research. Manufacturers still cling to old automatic ECG analyzers, whose clinical usefulness is questionable, and every ECG must be evaluated by a physician. This is due to the low diagnostic value of evaluation by current automatic analyzers.

The use of an effective and proven AI ECG would do much more than relieve the burden on those responsible for analyzing ECGs. Current research points out that AI models are able to read much more from a simple ECG recording than a human can [26, 32]. Assessing anemia or atrial fibrillation during sinus rhythm opens up a whole new avenue in screening and prevention of complications of these diseases. These conditions are elusive to the human eye and currently require much more invasive and expensive testing

AI algorithms could support doctors in diagnostic processes and speed up ECG analysis in hospital and prehospital settings.

Most of the resulting algorithms are models developed in single studies on a limited amount of data.

These studies do not describe how exactly the computer makes its diagnoses or evaluates me based solely on individual ECG elements. It is worth noting that most of the studies used 12-lead ECGs, while others used 6-lead or 1-lead ECGs. All of these algorithms should be investigated in a standardized way in a clinical setting.

In addition, it is important to remember that the algorithms should be trained, tested and validated in a variety of medical facilities; current models are mainly limited to single facilities.

Most ECG-based deep learning algorithms are designed based solely on raw ECG samples without other clinical data. In the future, systems could be constructed that, based on the ECG and, for example, laboratory results, would quickly suggest a diagnosis to help the doctor. The use of ECGs measured by smartwatches, which although recently introduced is steadily growing, will also undoubtedly increase in the future.

CONCLUSIONS

Artificial intelligence has increasingly permeated medicine over the years. Research on artificial intelligence in medical diagnosis, including ECG, will certainly continue in the future. However, it should be remembered that no neural network or computers can replace doctors, and their knowledge will always determine the final diagnosis and subsequent treatment of the patient.

It is important to responsibly create and understand the operation of new algorithms before they are put into general use.

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REVIEW ARTICLE

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Procedural sedation analgesia in prehospital settings: The state of the art

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ABSTRACT

The utilization of analgosedation procedures is progressively becoming more prevalent in conducting a diverse spectrum of procedures necessitated by the patient's clinical condition. Such procedures may be undertaken by physicians, anaesthesia nurses, and paramedics alike. Due to the broad competencies of employees of the state emergency medical system, it is possible to carry out analgosedation in the prehospital setting. However, performing analgosedation in that situation presents considerable challenges owing to limited familiarity with the patient's history, available equipment, and environmental conditions at the scene. Hence, prehospital healthcare providers must possess comprehensive knowledge of the procedural capabilities and technical skills associated with analgosedation to mitigate the risk of adverse events. Proficiently executed analgosedation, based on the conscious use of available equipment, medications and the procedure's capabilities holds significant importance in achieving the desired procedural outcomes and positively impacting the patient's clinical status. As no formal guidelines in analgosedation for prehospital providers have been developed the authors aimed to summarize current knowledge and skills required to minimize the risk for patients. The authors also aimed to highlight the necessity of responsible and thoughtful training to perform analgosedation in the prehospital setting to develop desirable correct habits and increase situational awareness.

KEY WORDS

paramedic, prehospital management, procedural sedation analgesia

INTRODUCTION

The base component of the Polish emergency medical services system are teams consisting of two paramedics. The professional competencies of paramedics were outlined in regulations established by the Minister of Health. According to these regulations, paramedics are allowed to independently administer 50 medications, including those that decrease consciousness levels. No supervision of physician is required [1-3].

Procedural sedation analgesia (PSA) is defined as a technique of administering sedatives or dissociative agents with or without analgesics to induce a state that allows the patient to tolerate unpleasant procedures while maintaining cardio respiratory function [4]. Analgosedation, derived from two distinct components, encompasses the administration of medications aimed at achieving both analgesic and sedative effects. The concept of analgosedation originates from the experience collected by professional's working in anesthesiology and intensive care units [5].

Several clinical situations when PSA may be necessary in prehospital environment should be considered. Those are, among others: an agitated trauma victim, transcutaneous pacing in severe bradycardia, electrical cardioversion in severe tachycardia with cardiovascular compromise, or the need mechanical ventilation.

AIM

This article aimed to delineate the fundamental principles necessary for the proficient and safe PSA within the prehospital environment. Furthermore, the authors aimed to introduce the theoretical framework encompassing the procedural steps of the PSA procedure.

REVIEW AND DISCUSSION

RISKS ASSOCIATED WITH SEDATION

Every healthcare professional who approaches PSA must be aware of the potential adverse events or severe complications that may arise during the procedure. In the study performed by Ricard-Hibon A et al., involving a cohort of spontaneously breathing individuals undergoing analgesia, adverse events were documented in 5.5% of cases. When also sedative agents were administered incidence rose to 16.6%. Predominant adverse events included nausea/vomiting, hypotension, and respiratory failure [6]. A meta-analysis conducted by Bellolio MF et al., the most common side effect was with an incidence of 40.2 per 1,000 sedations. This was followed by vomiting (16.4 per 1,000 sedations), and hypotension (15.2 cases per 1,000 sedations) [7]. Considerable number of patients are at risk of hypoxemia during PSA. In other study, positive correlation has been found with increasing duration of performed procedures [8]. About

5% of patients required face mask ventilation and 0.1% endotracheal intubation or supraglottic airway insertion [8]. The etiology of hypoxia may stem from respiratory depression induced by sedative and analgesic agents. Additionally, unnoticed compromise in airway patency represents another potential factor. To optimize patient safety during PSA, meticulous attention should be given to ensure proper preparation of the patient. Moreover, environment and equipment utilized in the procedure must be checked and ready to use.

Regrettably, there is currently a dearth of studies investigating the frequency of PSA performed within the prehospital environment in Poland. Consequently, the extent of procedural utilization, the incidence of adverse events, and the efficacy level of provided PSA remain undisclosed.

PATIENT ASSESMENT

Before any medical procedure, the patient must be informed and consent must be obtained. When PSA is required, consideration should be given to the patient's medical history. Questions should be posed: Have there been any prior complications experienced by the patient during sedation? Are there any underlying medical conditions that could potentially exacerbate the side effects of the administered drugs?

These considerations typically pertain to risk factors associated with difficult ventilation using a bag-valve-mask and difficult intubation. Prehospital PSA is typically reserved for situations involving life-threatening conditions. Therefore, all contraindications should be assessed with relative consideration. The prospect of encountering potential difficulties should prompt the implementation of comprehensive emergency preparedness measures in anticipation of such occurrences.

It should be noted that some chronic diseases may influence the risk of complications. For example, compromised cardiac function may intensify hypotension. In addition, chronic obstructive pulmonary disease can elevate the risk of apnea and hypoxia. Obesity or facial malformations can lead to difficulties in ventilation.

Potential risk for difficult ventilation as well as difficult intubation should be determined.

Acronyms BONES (Beard, Obesity, No Teeth, Elderly, Snoring) – for difficult ventilation assessment and LEMON (Look externally, Evaluate 3-3-2 rule, Mallampatti score, Obstruction, Neck Mobility) – for difficult intubation may be considered helpful [9].

PREPARATION OF THE ENVIRONMENT AND EQUIPMENT

It is important to recognize the inherent unpredictability of the patient's response to medications administered during PSA. Therefore, thorough preparation of both, equipment and personnel is crucial. This helps in effective managing with potential adverse events. The formulation of contingency plans can be facilitated by considering the most probable and severe side effects. It is noteworthy that occurrences of hypoxia and hypotension, particularly in critical life and health crises, are not uncommon and should be preemptively anticipated.

Table 1. The SOAPME acronym.

Suction	The suction device is prepared and in working order.
Oxygen	The patient is adequately oxygenated, and preoxygenation has been performed.
Airway	Respiratory protection equipment, including Bag-Valve-Mask (BVM) and Supraglottic Airway Devices (SAD), are prepared.
Pharmacy	PSA drugs, drug antagonists, and medications for sudden cardiac arrest (SCA) are prepared.
Monitor	The patient is being monitored for ECG, non-invasive blood pressure (NIBP), pulse oximetry (SpO_2), and end-tidal carbon dioxide ($EtCO_2$).
Equipment	All necessary equipment for procedure is available.

Table 2. Stage of Sedation according to American Society of Anesthologist [19].

	Minimal Sedation (Anxiolysis)	**Moderate Sedation /Analgesia (Conscious Sedation)**	**Deep Sedation /Analgesia**	**General Anesthesia**
Responsiveness	Normal response to verbal stimulation	Purposeful response to verbal or tactile stimulation	Purposeful response after repeated or painful stimulation	Unarousable, even with painful stimulus
Airway	Unaffected	No intervention required	Intervention may be required	Intervention often required
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

Table 3. Medications for analgosedation performed by paramedics in Poland [24-28].

Medication	Dose for adults	Dose for children	Start of action (min)	Action peak (min)	Reverse Agent	Side effects
Diazepam	0.05-0.2 mg/kg iv	Initial 0.05-0.1 mg/kg, max 0.25 mg/kg iv	1-5	5-10	Flumazenil- initial dose 0.2 mg, repeat 0.1 mg, max 1 mg	Respiratory depression
Midazolam	Initial 2-2.5 mg iv, repeat 1 mg every 2-5 min, >60 years 0.5-1.0 mg, max 3.5 mg	0.5-5 years- initial 0,05-0,1 mg/kg, max 0,6 mg/kg iv 6-12 years- initial 0.025-0.05 mg/kg, max 0.4 mg/kg iv	2-3	5-10	Flumazenil- initial dose 0.2 mg, repeat 0.1 mg, max 1 mg	Increased heart rate, respiratory depression
Morphine	2-4 mg iv (0.05-0.1 mg/kg)	Initial 0.05-0.15 mg/kg iv up to 3mg/dose, may repeat every 5 minute	3-5	30-60	Naloxone 0.1-0.4 mg iv, max 1.0 mg	↓HR and RR, nausea, vomiting, bronchospasm dependent on histamine release
Fentanyl	Initial 1-1.5 ug/kg iv, repeat 1 ug/kg every 3 min	Initial 1.0 ug/kg up to 50 ug/dose iv, may repeat every 3 min	1-2	5-15	Naloxone 0.1-0.4 mg iv, max 1.0 mg	↓HR and RR, respiratory depression
Ketamine	1.0-1.5 mg/kg iv, 3.0-4.0 mg/kg im	1.0-1.5 mg/kg iv, 3.0-4.0 mg/kg im	1	1-5	-	↑HR and BP, agitation, laryngospasm, hallucinations

The consequences of compromised airway patency can be severe, potentially leading to catastrophic outcomes. The use of the mnemonic SOAPME [10] may be helpful in outlining the strategic components in preparation the environment for PSA. The SOAPME mnemonic was presented in Table 1.

The patient's clinical status and the aim of PSA play pivotal roles in guiding procedural decisions. Usual life-threatening conditions occur suddenly, unpredictably. Hence it is not always possible to keep the patient fasting. The multidisciplinary International Committee for the Advancement of Procedural Sedation recommends clarifies fasting time for PSA. It as been highlighted that if urgent or emergency procedures are performed, no delay based on fasting time should be present or ketamine should be used as the sole agent [11].

Ready to use suction device is essential to address potential oral contents during the procedure. Adequate preoxygenation, entailing ventilation ideally lasting 3-4 minutes utilizing a face mask equipped with a reservoir and an oxygen flow exceeding 10 liters per minute [12], should precedes the intervention. This ensures oxygen reserve to keep saturation levels for even up to 8 minutes in case of respiratory arrest [13]. Routine monitoring of end tidal CO2 reduces incidence of hypoxemia during procedural sedations [14]. Therefore, integration of capnography for continuous monitoring of respiratory waveforms is crucial. In instances of absent spontaneous breathing and declining saturation levels, prompt initiation of ventilation must be done. Meticulously prepared equipment for both non-instrumented and instrumented airway clearance, as well as proficiency in ventilation techniques, serves to avert catastrophic hypoxemia.

Another factor necessary to ensure the safe PSA is selection of pharmacological agents tailored to individual patient needs and precise dosage calculations. Availability of antagonistic agents to counteract the effects of analgosedation drugs is indispensable in the event of sever adverse reactions. Vigilant monitoring throughout the procedure, facilitates early detection of and timely interventions to mitigate the risk of severe complications. Full vitals monitoring includes: electrocardiography (ECG), pulse oximetry (SpO2), non-invasive blood pressure (NIBP), respiratory rate (RR), heart rate (HR), and, when feasible, end-tidal carbon dioxide (EtCO2),

SEDATION DEPTH AND RATING SCALE

The ability to determine the depth of sedation with relevant assessment scales ensures proper PSA. Some studies indicate that early initiation of deep sedation in intubated patients leads to prolonged ICU stays [15]. The study from France, revealed that merely 29% utilized a sedation scale when managing mechanically ventilated patients, underscoring the urgent need to advocate for the systematic adoption of such assessment tools [16]. Two commonly used in emergency

medicine scales are: the Ramsay Sedation Scale [17] and the Richmond Agitation-Sedation Scale [18]. However, the scale devised by the American Society of Anesthesiology, owing to its extensive expertise, is widely endorsed and deemed particularly suitable for prehospital settings (Table 2) [19].

A reliable method to confirm attainment of the desired level of sedation/analgesia is patients' responsiveness to commands. It is noteworthy that verbal responses from patients serve as indicators of ongoing respiration, while reflex withdrawal in response to painful stimuli signifies deep sedation.

MEDICATIONS

In polish paramedic-staffed teams, several medications ensure PSA. Those are: fentanyl and morphine (analgetics) as well as midazolam and diazepam (sedatives). Consultants from the American Society of Anesthesiologists unanimously advocate for the combined use of analgesic and sedative agents to achieve an optimal level of moderate to deep sedation. However, it is important to acknowledge that previously published data suggest a potential increase in the risk of side effects. Those include respiratory depression and hypoxemia, with the use of sedatives and opioids in combination. It has been also emphasized, both components should be administered separately. This warrants better control of desired effect. The propensity of sedative and analgesic drugs to induce respiratory depression and airway obstruction underscores the importance of dose adjustment for each component accordingly [19].

Studies comparing the effectiveness of different drug combinations, such as diazepam with fentanyl versus midazolam with fentanyl, have revealed no significant differences in efficacy. However, educed pain and enhanced muscle relaxation observed with diazepam and fentanyl combination [20]. Similarly, a comparison of propofol versus midazolam for sedation in a pediatric emergency department demonstrated comparable sedative efficacy but faster recovery with propofol administration [21]. This proves that midazolam-led sedation may be as effective as propofol-led. However, studies examining the combined effects of midazolam and fentanyl on respiratory parameters during sedation have indicated an increased risk of hypoxemia and apnea, necessitating stringent monitoring and specialized airway management [22]. Conversely, investigations into the efficacy and safety of fentanyl in combination with midazolam in mechanically ventilated children have shown significantly improved efficacy and safety profiles compared to the use of midazolam alone [23].

Given the ongoing discussion about allowing paramedics to administer ketamine, the authors decided to include it in this review. However according to Polish regulation it is not allowed for paramedics in prehospital settings. Recent studies have demonstrated the notable efficacy of guided analgosedation when utilizing ketamine. As the sole agent, ketamine exhibits dual analgesic and sedative properties. Unlike propofol and midazolam, ketamine does not exert adverse effects on blood pressure – it often results in an increase, rendering it particularly suitable for patients with hypotension. The use of ketamine reduces opioid requirement [29]. The drug can be administered by various routes, including intranasally and intramuscularly, which makes ketamine suitable for use in cases where intravenous access is not possible. Additionally, ketamine has been observed to enhance lung compliance and preserve the pharyngeal reflex, although it may precipitate laryngospasm. These mechanisms contribute to a reduce risk of respiratory depression, distinguishing ketamine from opioid medications such as fentanyl or morphine. One of the side effects associated with ketamine is psychosis and hallucinations, with no clear dose-response relationship established. In summary, ketamine emerges as a valuable alternative in the prehospital setting for patients requiring PSA [30-32].

For optimal management, it is advisable to incrementally titrate drug dosages by administering small, repeated doses until achieving the desired level of sedation and maintaining normal responsiveness. These measures serve to mitigate the risk of excessive sedation and associated complications. The continuous provision of sedation following intubation and mechanical ventilation presents numerous challenges.

Continues sedation necessitates the availability of appropriate drugs and infusion pumps. Unfortunately, in Polish state emergency medical service, limited number of ampules in ambulance, poses a risk of inadequate supply [33]. Unlike the well-equipped emergency departments, anesthesiology, and intensive care units, the prehospital environment is characterized by its dynamic nature and lack of resources. Consequently, there is heightened reliance on the proficiency in analgosedation to ensure patient comfort and airway patency.

TRAINING

Simulation training leads to improved patient flow and significant cost savings from avoiding unnecessary hospitalizations [34]. It has been also found as clinically relevant as well as effective at improving comfort level in caring for critically ill patients [35]. Simulation-based medical education is a powerful intervention to increase the competence of medical learners and can contribute to better patient care and safety [36]. Tobin et al. proved, that introduction of a simulation course for PSA training increases clinical knowledge, technical skills and coping skills. Additionally, participants rated this method better than lecture. The program included: online training materials, and 8-hour simulation-based course during where participants could deal with difficult airway, adjust drug doses, and recognize different levels of sedation [37]. Therefore, high-fidelity simulation-based PSA training should be an obligatory part of the pre- and postgraduate training for paramedics.

CONCLUSIONS

Prehospital PSA is essential in critical and life-threatening events. Comprehensive preparation, including medication knowledge, and access to appropriate equipment are vital for patient safety. Utilizing sedation depth scales is invaluable for managing potential side effects.

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REVIEW ARTICLE

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Yes or no for extracorporeal cardiopulmonary resuscitation? PART 1. GUIDELINES AND RECOMMENDATIONS. REVIEW OF INCLUSION AND EXCLUSION CRITERIA

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ABSTRACT

The incidence of unexpected cardiac arrest is high. Survival to hospital discharge after cardiac arrest is low. Searching of methods improves cardiac arrest outcomes, started research with use extracorporeal membrane oxygenation. The application of venoarterial extracorporeal membrane oxygenation during cardiac arrest is extracorporeal cardiopulmonary resuscitation. When guideline-directed resuscitation efforts fail to achieve return of spontaneous circulation , an episode of cardiac arrest is deemed refractory and extracorporeal membrane oxygenation may be considered.

The article reviews the current literature for the dates 01/01/2018 to 31/12/2023 (last 5 years) in the field of extracorporeal cardiopulmonary resuscitation, paying particular attention to:

- current guidelines and recommendations;
- inclusion and exclusion criteria taking of regional and national experiences;
- results of studies on the effectiveness of extracorporeal cardiopulmonary resuscitation and comparative studies of extracorporeal cardiopulmonary resuscitation with conventional cardiopulmonary resuscitation
- decision making, logistics, trends and discussions,

to create a database for the reader, who expects an answer to the question: yes or no for extracorporeal cardiopulmonary resuscitation?

KEY WORDS

extracorporeal cardiopulmonary resuscitation, out of hospital cardiac arrest, in hospital cardiac arrest, cardiopulmonary resuscitation, ECPR

INTRODUCTION

The incidence of unexpected cardiac arrest (CA) is high. Survival to hospital discharge after CA is low. Searching of methods improves CA outcomes, started research with use extracorporeal membrane oxygenation (ECMO). The application of venoarterial ECMO (VA ECMO) during CA is extracorporeal cardiopulmonary resuscitation (ECPR). Does it work?

DEFINITION OF ECPR AND INDICATIONS TO ECPR

ECMO is a combination of a blood pump and an oxygenator that can be used to support either pulmonary or both pulmonary and cardiac function; venovenous (VV) or venoarterial (VA) configurations, respectively. ECPR is used to describe the use of venoarterial ECMO in refractory cardiac arrest (RCA). The increased adoption of ECPR has been facilitated by the advent of small, portable ECMO devices and circuit improvements. Attributable to advances in ECMO technology, it is possible to deliver either partial or full cardiorespiratory support for weeks or months, if required.

An ECMO circuit consists of a centrifugal pump and a membrane oxygenator for oxygen delivery, CO_2 removal, and temperature management. In ECPR, VA ECMO is established while cardiopulmonary resuscitation (CPR) is ongoing. The drainage (access) cannula is placed into the inferior vena cava *via* the femoral vein, and the "return" cannula is inserted into the femoral artery to the level of the common iliac artery [1].

ECPR is the application of ECMO in patients where conventional cardiopulmonary resuscitation (CCPR) measures are unsuccessful in achieving a sustained return of spontaneous circulation (ROSC). The primary purpose of ECPR is to restore the circulation and gas exchange. By providing organ perfusion, it provides time for the delivery of interventions necessary to regain an adequate native circulation. These may include percutaneous coronary intervention (PCI) and recovery from myocardial stunning, pulmonary thrombectomy, rewarming, or toxin clearance [2].

When guideline-directed resuscitation efforts fail to achieve ROSC, an episode of CA is deemed refractory and ECPR may be considered. However, there is no universally agreed upon timing of when CA is RCA, previously defined on the basis of CPR length, number of defibrillations, doses of epinephrine or amiodarone, or a combination of

these. In the setting of CA, a shorter time to initiation of ECMO has been previously associated with favorable neurologic outcome, which may make defining CA as refractory based upon CPR duration alone excessively limiting. For shockable rhythms it may be better to use defibrillation attempts as the main criteria for defining RCA, though for nonshockable rhythms CPR duration may be the only variable available.

Until randomized controlled trials are done to provide firm indications for the use of ECPR, RCA will continue to be defined on the basis of CPR duration or failure to achieve ROSC following multiple defibrillation attempts at the discretion of the ECMO provider. Generally when defining RCA, CA that persists despite continuous CCPR lasting 10–30 min or after three attempted defibrillations is considered refractory [3].

For example, the introduction presents:

1. Possible indications (not criteria) for ECPR (Germany) [4]:
   - PCI and recovery from myocardial stunning in patients with acute myocardial infarction (AMI),
   - thrombolysis or thrombectomy for massive pulmonary embolism (PE),
   - rewarming in the event of accidental hypothermia,
   - cardiotoxic acute life-threatening poisoning or hyperkalemia
   - hypoxia and respiratory failure.
2. Indications and contraindications (not criteria) for ECPR (China) [5]:
   a) indications:
      - the etiologies of CA are reversible (such as cardiogenic, PE, severe hypothermia, drug poisoning, trauma, acute respiratory distress syndrome, etc.),
      - organ donation,
      - likely to receive an immediate heart transplant,
      - COVID-19 patients with severe heart failure or CA.

   b) absolute contraindications:
      - severe neurologic disease with poor prognosis before CA,
      - pre-existing uncontrolled intracranial bleeding or bleeding at other sites,
      - pre-existing terminal illnesses such as metastatic malignancy and end-stage organ dysfunction,
      - patient refuses ECPR.

   c) relative contraindications:
      - untreated aortic dissection and aortic valve insufficiency.
      - impossible cannulation due to severe vascular anomalies or previous surgical interventions.
      - sepsis shock,
      - advanced age (aged >75 years)
      - low-flow duration in CA >60 min.

THE AIM

The article reviews the current literature in the field of ECPR, paying particular attention to:

- current guidelines and recommendations;
- inclusion and exclusion criteria taking of regional and national experiences;
- results of studies on the effectiveness of ECPR and comparative studies of ECPR with CCPR;
- decision making, logistics, trends and discussions,

to create a database for the reader, who expects an answer to the question: yes or no for ECPR?

MATERIAL AND METHODS

The MEDLINE database (full access) was searched for the terms "ECPR" and "extracorporeal cardiopulmonary resuscitation" for the dates 01/01/2018 to 31/12/2023 (5 years), paying particular attention to the guidelines and recommendations; inclusion and exclusion criteria, results of prospective randomized studies, metaanalyses of prospective randomized studies; results of retrospective studies (metaanalyses, systematic reviews, comparative studies, individual studies with a large sample); decisions; logistics and trends.

REVIEW AND DISCUSSION

GUIDELINES AND RECOMENDATIONS FOR ECPR

ECTRACORPOREAL LIFE SUPPORT ORGANISATION (ELSO)

ECPR can be deployed both for patients with in-hospital cardiac arrest (IHCA) and out of hospital cardiac arrest (OHCA). ECPR should be considered after 10–15 minutes of unsuccessful conventional resuscitation efforts, because organization and preparation for ECPR will take some time and it has been clearly shown that time to ECMO correlates with neurologic outcome [2].

EUROPEAN RESUSCITATION COUNCIL (ERC)

ECPR is used to support circulation in patients with RCA to CCPR. ECPR maintains vital organ perfusion while potential reversible causes of the CA can be identified and treated. ECPR can be considered in select patients when rapid expert deployment is possible; however, the optimal patient selection and timing of the therapy are not well defined.

We suggest that ECPR may be considered as a rescue therapy for selected patients with CA when CCPR is failing in settings in which it can be implemented (weak recommendation, very low certainty of evidence) [6].

AMERICAN HEART ASSOSCITION (AHA)

ECPR is a complex intervention that requires a highly trained team, specialized equipment, and multidisciplinary support within a healthcare system. The 2019 focused update on ACLS guidelines addressed the use of ECPR for CA and noted that there is insufficient evidence to recommend the routine use of ECPR in cardiac arrest.

Table 1. Example of inclusion criteria to ECPR [2].

Age <70 years
Witnessed arrest
Arrest to first CPR ("no-flow interval") < 5 minutes (i.e., bystander CPR)
Initial cardiac rhythm of VF/pVT/PEA
Arrest to ECMO flow < 60 minutes "low flow interval"*
$ETCO_2$ > 10 mmHg (1.3 kPa) during CCPR before cannulation for ECMO
Intermittent ROSC or recurrent VF
"Signs of life" during CPR may be a positive predictive factor for survival
The absence of previously known life limiting comorbidities (e.g. end stage heart failure/chronic obstructive pulmonary disease/end-stage renal failure/liver failure/terminal illness) and consistent with patient's goals of care
No known aortic valve incompetence (>mild aortic valve incompetence should be excluded)

* Unless other favorable prognostic features are present: e.g., periods of intermittent ROSC/hypothermia prearrest/young age/signs of life during CPR

Table 2. Germany; possible decision criteria with regard to ECPR from: recommendations for extracorporeal cardiopulmonary resuscitation [8].

Inclusion criteria	Exlusion criteria
• observed CA • presumed cardiac aetiology, especially defibrillatable initial heart rhythm • no-flow time ≤ 5 min • short low-flow time ≤ 60 min • consistently high-quality resuscitation measures (effective resuscitation by lay responder/s) • presence of a reversible cause of the CA (4 H's and HITS). This includes hypoxia, hypovolaemia, hypo-and hyperkalaemia (metabolic dysfunctions), accidental hypothermia, pericardial tamponade, intoxication, thromboembolism (myocardial infarction (MI), PE) and tension pneumothorax	• age > 75 years and frailty • non-observed CA • no-flow time ≥ 10 min • clinical signs of severe irreversible brain damage or expected poor neurological prognosis • inadequate resuscitation measures (e.g. absent, doubtful or intermittent resuscitation by lay responder/s) • comorbidities with reduced life expectancy (e.g. underlying oncological condition under palliative care, terminal heart failure or COPD, advanced dementia) • prolonged CPR of > 20 min in the case of asystole (exception: accidental hypothermia, intoxication, near-drowning and suspected PE) or of > 120 min in the case of persistent VF/VT • low pH (< 6.8) and high lactate (> 20 mmol/L) • patient's refusal (advance directive, the presence of emergency sheet regarding) • contraindications to full anticoagulation (e.g. active bleeding)
As the decision for or against ECPT should not depend solely on 'one' indication or 'one' contraindication, terms such as absolute or relative indication or contraindication have been deliberately avoided. No-flow time is defined as the time from the collapse event to the initiation of CPR; conversely, the low-flow time is defined as the interval from the start of CPR to ROSC of ECPR	

Table 3. France, National Guidelines for ECPR to RCA [1].

Inclusion criteria (≥ 1 condition is met)
• adults older than 18 y and those younger than 65 y • RCA (defined by the failure of professionals to resuscitate at the 20th min of CA with a minimum of 3 defibrillator shocks) • beginning of CCPR within the first 5 min after CA (no-flow duration <5 min) with shockable rhythm or the presence of signs of life during resuscitation (any rhythm) • medical cause of the CA • end-tidal CO_2 >10 mm Hg at the time of inclusion • absence of major comorbidities and ECPR team available on-site within 40 min of CA

Table 4. USA, Minnesota (ARREST trail) [9].

Inclusion criteria	Exlusion criteria
VT/VF as first presenting rhythm 18–75 years of age three EMS-delivered direct current shocks without achieving ROSC body morphology able to accommodate a Lund University Cardiac Arrest System automated CPR device estimated transfer time to the scene of the cardiac catheterization laboratory <30 minutes efficient CPR (end-tidal carbon dioxide <10 mmHg, PaO_2 <50 mmHg, lactate <18 mmol/l)	non-shockable rhythm (asystole or pulseless electrical activity) CA of non-cardiac etiology contraindications to mechanical CPR known pregnancy known prisoners nursing home residents valid do not resuscitate/do not intubate orders known terminal illness absolute contraindication to angiographic contrast media active gastrointestinal or internal bleeding

Table 5. Canada (Protocol for Paramedics in Atlantic Canada, Pilot Knowledge Translation Project) [10].

Inclusion criteria	Exlusion criteria
witnessed OHCA age 18-70 no flow time < 10 mins (from arrest to initiation of CPR) 10 minutes or 3 rounds of CPR completed (whichever comes first) without ROSC PEA/VT/VF as heart rhythm mechanical chest compression device available cardiac catheterization Lab open (7 am – 7 pm) ≤20-minute transport time to hospital	unwitnessed CA asystole after initial resuscitation (at the time of transport decision) auspected etiology: uncontrolled bleeding; irreversible brain damage; trauma comorbidities: standing do-not-resuscitate order; undergoing end-of-life care; unable to fit mechanical chest compression device on patient pregnancy

Table 6. Netherland; (INCEPTION, multicenter trail) [11].

Inclusion criteria	Exlusion criteria
≥18 - ≤70 years witnessed OHCA initial rhythm of VF/VT or AED-shock administered bystander BLS no ROSC within 15 minutes	ROSC with sustained hemodynamic hemodynamic recovery within 15 minutes terminal heart failure (NYHA III or IV) severe pulmonary disease (COPD GIII of GIV) oncological disease pregnancy bilateral femoral vessel bypass surgery pre-arrest CPC score of 3 or 4 multiple trauma (Injury Severity Score> 15) advance health care directive expected initiation of cannulation >60 min after arrest

Table 7. USA, Michigan, (EROCA trail) [12]

Inclusion criteria	Exlusion criteria
present with OHCA, presumed non-traumatic etiology and requiring CPR age presumed or known to be 18 through 70 years old (prior to 71st birthday) predicted 911 call to arrival time at ECPR-capable ED interval predicted to be within 30 minutes initial shockable rhythm (VT/VF) or witnessed arrest with PEA or asystole as presenting rhytm persistent CA after initial manual paramedic cardiac rhythm analysis and shock if indicated.	Do Not Attempt Resuscitation or Do Not Intubate advanced directive pre-existing evidence of opting out of study prisoner pregnant (obvious or known) ECPR-capable ED is not at the destination hospital as determined by EMS destination protocol legally authorized representative aware of study and refuses study participation at the scene

Table 8. United Kingdom of Great Britain, Barts & The London NHS Trust [13]

Inclusion criteria	Exlusion criteria
visible age 18-65 have a witnessed OHCA have a presumed cardiac aetiology to their CA receive bystander chest compressions within 3 min remain in CA at 20 min following collapse or fail to sustain ROSC in the pre-hospital setting	known or visibly advanced pregnancy (when resuscitative hysterotomy will be prioritised) absent signs of life (physical movements or spontaneous respiratory effort) AND evidence of ineffective chest compressions which will be suggested by: a) absence of electrical activity on the electrocardiogram OR b) an end tidal expired carbon dioxide level of less than 1.3 kPa (10 mmHg) evidence from others present at the scene or patient examination that ECMO is unlikely to provide long-term benefit for the patient (e.g. advanced malignancy, severe frailty, terminal comorbid condition)

Table 9. Australia, Sydney (2-CHERR trail) [14]

Inclusion criteria	Exlusion criteria
Patient with OHCA refractory to CCPR were eligible for ECRP if they were aged 12-70, and: the CA was likely to be of promary cardiac or respiratory cause (including myocyrdial depression secondary to hypothermia or drug effects) the CA was witnessed and chest compressions commedced within 10 min initial cardiac rhytm of VF/VT immediate availability of a mechanical CPR device with paramedic staf; the CA diuration (collapse to arrival time at ED less than 60 min)	patients were excluded if there was active bleeding, if it was known the patient did not want to receive invasive resuscitation, or if the patient had a pre-exsisting comorbidity and/or funcional limitation such that it would prevent a future return to independent life

Table 10. Czech Republic; Prague, (Praque OHCA trail) [15]

Inclusion criteria	Exlusion criteria
Adults aged 18 to 65 years receiving ongoing resuscitation for witnessed OHCA of presumed cardiac etiology were eligible for enrollment in the trial, given that they had received a minimum of 5 minutes of advanced cardiac life support without ROSC and when the ECPR team was available at the cardiac center	Patients who had unwitnessed CA or presumed noncardiac cause, had suspected or confirmed pregnancy, attained ROSC within 5 minutes during initial resuscitation, regained consciousness, had obvious life-limiting comorbidities, bleeding diathesis, known do-not-resuscitate order, or known prearrest Cerebral Performance Category (CPC) 3 or greater were excluded

Table 11. Norway, Oslo [16]

Inclusion criteria	Exlusion criteria
presumed cardiac cause witnessed arrest bystander resuscitation shockable first rhythm (VF or VT) age 18–65 paramedic CPR within 15 min >10 min of ALS without ROSC <60 min from CA to ECMO cannulation*	CA due to uncontrolled haemorrhage long-term oxygen therapy dialysis diabetes with severe secondary complications expected life span <1 year known low compliance with treatment substantial existing CNS deterioration terminal stage of pulmonary disease

*<60 min from CA to ECMO cannulation is a criterion in the ECPR protocol but did not exclude patients from being part of the sample

Table 12. Canada, British Columbia, BC ECPR Trial for Out-of-Hospital Cardiac Arrest [17]

Inclusion criteria	Exlusion criteria
intra-arrest treatment by an ALS paramedic age ≥ 18 and ≤ 65 years witnessed CA bystander CPR required if initial rhythm is pulseless electrical activity (added to the protocol June, 2018 and applied retrospectively) cause of the CA is presumed to be one of the following: no obvious non-cardiac cause is identified known overdose of one of the following drugs: beta-blocker, calcium channel blocker, tricyclic antidepressants or other psychiatric medications, or digoxin hypothermia (with T < 32°C) the patient remains pulseless after a minimum of 3 cycles of CPR (by any professional provider)	an alternate cause of the arrest is most likely Do Not Resuscitate status co-morbidities including congestive heart failure, chronic obstructive pulmonary disease or other significant lung disease, dialysis, liver failure (if co-morbidities are unknown to paramedics they will be assumed not present) active malignancy pre-existing major neurological deficit asystole (added to the protocol June, 2018 and applied retrospectively)

Table 13. Belgium, Liege [18]

Prehospital inclusion criteria	Prehospital exclusion criteria
age < 65 years no major comorbidity no flow < 3 minutesb or cortical signs of life during CPR low flow < 60 minutes initial shockable rhythm $ETCO_2$ > 15 mmHg	major comorbidities: medical: extensive stroke, advanced dementia, O_2-dependant COPD, or fibrosis, Child C cirrhosis, frailty in dialysis, palliative cancer vascular: end-stage arteriopathy, severe aortic disease, morbid obesity is considered as prolonged no flow: unwitnessed CA poor-quality of CPR by bystander (eg, insufficient rate or depth of external chest compression, soft surface) initial non-shockable rhythm absence of shock by automated external defibrillator is assimilated to a non-shockable rythm
	Hospital resuscitation discontinuation criteria
	extreme metabolic acidosis (pH < 7.0d with lactate > 1800 mg/L) or hypoxia (PaO_2 < 50 mmHg, SaO_2 < 80%) $ETCO_2$ < 10 mmHg for > 20 minutes refractory vasoplegia general ECMO contraindications (eg, aortic, traumatic, hemorrhagic, limitation…)

a) physiological age is most relevant,
b) if severe hypothermia, consider no flow < 1 hour, low flow < 6 hours, and all rhythms,
c) cortical signs of life: attempts of head/member oriented moving, speaking, eyes opening and moving

Table 14. Japan, Osaka (criteria from Save-J trail) [19]

Inclusion criteria	
VF/VT on the initial ECG CA on hospital arrival with or without pre-hospital ROSC within 45 min from reception of the emergency call or the onset of CA to the hospital arrival, and no ROSC at least during the 15 min after hospital arrival (or after contact with a doctor) even though conventional CPR was performed	under the age of 20 years or those aged 75 years or older poor level of activities of daily livings before the onset of cardiac arrest non-cardiac origin (e.g., external factors such as trauma and drug intoxication, primary cerebral disorders, acute aortic dissection diagnosed prior to the introduction of PCPS, and terminal phase of cancer), core body temperature of less than 30°C, and no informed consent from the individuals representing patients

Table 15. Hongkong [20].

Inclusion criteria	Exlusion criteria
potentially reversible cause of CA but did not have ROSC after more than 30 minutes of conventional CPR	age 60 years or older prolonged CA more than 60 minutes before assessing candidacy for ECMO unwitnessed CA more than 10 minutes without BLS asystole upon arrival to ER, and pre-existing end-stage organ failure, malignancy, or irreversible cause of CA.
Due to the highly-variable presentation of patients and the uncertainties around ascertaining patient history during resuscitation, all exclusion criteria were considered relative and the final decision for ECPR was left to the discretion of the attending physician	

Table 16. USA, Minneapolis [21].

Prehospital inclusion criteria	In hospital exlusion criteria
age 18–75 years OHCA of presumed cardiac etiology initial cardiac arrest rhythm of VF/VT received 3 direct current shocks without ROSC received Amiodarone 300 mg body habitus accommodating a Lund University Cardiac Arrest System (LUCAS®) automated CPR device, and estimated transfer time to the cardiac catheterization laboratory (CCL) of <30 min	end-tidal CO_2 < 10 mmHg PaO_2 < 50 mmHg lactic acid >18 mmol/L, and time from EMS activation to CCL arrival >90 min.
Patients were transported with mechanical CPR and ongoing ALS directly to the CCL and immediately assessed for effective resuscitation on CCL arrival	

Table 17. Italy, Mediolan (metropolitan protocol) [22]

Inclusion criteria	Exlusion criteria
age between 12 and 75 years no-flow time from collapse to team (BLS) arrival equal or less than 6 min end-tidal CO_2 (ET-CO_2) equal or more than 10 mmHg after 20 min of CPR low-flow time from collapse to hospital admission equal or less than 45 min	end-stage cardiomyopathy with no transplant indication, severe aortic valve regurgitation aortic dissection, peripheral vasculopathy terminal malignancy
A mechCPR compression device was not mandatory, although strongly recommended since guidelines suggested its use during transport; given the observational and pragmatic nature of the study, the treatments offered by medical teams were different depending on the physicians' choices	

Table 18. China, Tianjin [5].

Indications	Absolute exclusion containducations
patients aged 18 to 75 years CA with witnesses and continuous CCPR was performed by bystanders the time interval from CA to the initiation of continuous high-quality CCPR should not exceed 15 min absence of ROSC, unstable hemodynamics, or presence of ROSC, but autonomic rhythm cannot be maintained after prolonged CCPR for 20 min the etiologies of CA are reversible (such as cardiogenic, pulmonary embolism, severe hypothermia, drug poisoning, trauma, acute respiratory distress syndrome, etc). organ donation. Likely to receive an immediate heart transplant COVID-19 patients with severe heart failure or CA	severe neurologic disease with poor prognosis before CA. pre-existing uncontrolled intracranial bleeding or bleeding at other sites pre-existing terminal illnesses such as metastatic malignancy and end-stage organ dysfunction patient refuses ECPR
	Relative exclusion containducations
	untreated aortic dissection and aortic valve insufficiency impossible cannulation due to severe vascular anomalies or previous surgical interventions sepsis shock advanced age (aged >75 years) low-flow duration in CA >60 min

However, ECPR may be considered if there is a potentially reversible cause of an CA that would benefit from temporary cardiorespiratory support. One important consideration is the selection of patients for ECPR and further research is needed to define patients who would most benefit from the intervention. Furthermore, the resource intensity required to begin and maintain an ECPR program should be considered in the context of strengthening other links in the Chain of Survival. Additional investigations are necessary to evaluate cost-effectiveness, resource allocation, and ethics surrounding the routine use of ECPR in resuscitation [7].

PATIENT SELECTION. INCLUSION AND EXLUSION CRITERIA TO ECPR

ELSO

Robust data to identify those who may benefit from ECPR are lacking. Protocols and guidelines strive to identify cases most likely to survive with favorable neurologic outcome, such as those patients who are witnessed to arrest and in whom high-quality CPR was initiated rapidly, in addition to cardiac arrests with a presumed reversible pathology, such as acute coronary occlusions.

We recommend that locally agreed inclusion criteria be formulated to guide clinicians on balancing the wise use of resources amongst patients who are thought to have an improved chance of survival following CA (Table 1) [2].

INCLUSION AND EXLUSION CRITERIA FOR ECPR OF NATIONAL OR REGIONAL CENTERS OR ORGANISATIONS

National or regional centres or organisations define their own criteria for ECPR, adapthig them to conditions and capabieleties of locals emergency medical services (EMS). Section presents selected inclusion and exlusion criteria for ECPR (MEDLINE database) (Table 2-16).

CONCLUSIONS

Successful outcomes after ECPR depend on the appropriate selection of patients. Broad inclusion criteria are likely to increase the number of patients who will benefit from prehospital ECPR, but increasing the number of patients will likely reduce the number of patients with good neurological outcomes.

Based on the review, it can be seen that local protocols contain a number of identical inclusion and exclusion criteria and also contain distinctive, different criteria for selecting patients for ECPR. Local inclusion criteria, tailored to health systems, help evaluators balance the wise use of resources among patients who are considered to have a greater chance of survival after CA.

Additionally, perhaps due to differences in inclusion and exclusion criteria to ECPR, based on survival outcome analyses, will be possible to undertake further research or draw conclusions, answer on questions: which inclusion and exclusion criteria are effective, which inclusion and exclusion criteria to use or not to use.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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REVIEW ARTICLE

Ventilator-associated tracheobronchitis (VAT) – systematic review

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ABSTRACT

Ventilator-associated tracheobronchitis (VAT), along with the relatively well-studied ventilator-associated pneumonia (VAP), form the ventilator-associated lower respiratory tract inflammation (VA-LRTI) disease group, which is undoubtedly a significant challenge for Intensive care units (ICUs) staff caring for mechanically ventilated patients daily. Recently, the topic of VAT has been increasingly addressed and researched to better understand and comprehend this disease unit. Despite its still uncertain definition, VAT is recognized as a disease entity independent of VAP, considered by many researchers to be either an intermediate stage or a risk factor for faster progression of VAP. Based on the available literature and the experience of the authors, we have selected 31 articles published between 2004 and 2023 that are both research and review papers in order to systematise the basic information and diagnosis of VAT, as well as to show the complexity of the problem, which is the issue of treatment and co-occurrence of VAT in critical patients as well as complicated by other respiratory diseases. It is hoped that this review will allow will enable medical personnel, especially those who work on a daily basis with patients undergoing mechanical ventilation, to look at VAT from a different angle and encourage further research to understand it better.

KEY WORDS

ventilator-associated tracheobronchitis, ventilator-associated pneumonia, ventilator-associated lower respiratory tract inflammation, intensive care unit, mechanical ventilation, critically ill patient

INTRODUCTION

For many years there was debate about how, or even if, we should separate ventilator-associated tracheobronchitis (VAT) from ventilator-associated pneumonia (VAP) and, if so, how we should define it. Fortunately, scientists came to an agreement and nowadays, VAT is defined as a lower respiratory infection of intubated mechanically ventilated patients with no radiological infiltrate present, and it affects more than 10% of invasively ventilated ICU patients [1]. All theories of the causes of VAT are in agreement. It is believed that the reason is the colonization of the lower respiratory tract by pathogens. Colonization occurs in patients after endotracheal tube (ETT) or oro-nasal tube (OG/NT) intubation . The authors consider leakage of the ETT cuff or its lumen as the cause [2]. The ETT biofilm, which enters the lower airway during mechanical ventilation, is also a factor promoting colonization [1]. The chances of VAT are related to the number, virulence and type of bacteria, and the host's defence mechanizes [3]. Pathogens isolated from patients with VAT are often multidrug-resistant bacteria (MDR) [4] Despite differences between different intensive care units (ICUs), Gram-negative bacteria are most common, which mainly include *Pseudomonas aeruginosa*, *Klebsiella pneumoniae* and *Escherichia coli*. The incidence of *Staphylococcus aureus* is also important [3].

THE AIM

The aim of this publication is to show readers the still unclear and inconsistent definition and management algorithms regarding ventilator-associated tracheobronchitis (VAT) and to clarify such a state of facts. In writing this review, we have attempted to enable the reader to gain the most in-depth understanding of each aspect of this disease through one collective work. Also, it is intended to encourage clinicians, especially those working with patients undergoing ventilator therapy, to be mindful of the existence of this disease entity and, if possible, to undertake further research, particularly regarding prevention and treatment.

REVIEW AND DISCUSSION

VAT DIAGNOSIS

VAT diagnosis was for a long time not standardised, resulting in many inaccuracies and difficulties. Currently, the criteria for clinical symptoms and microbiological culture results are found in many combinations, making the only unquestionable criterion in the medical com-

munity seem to be the radiological criterion. Confirmation of the lack of standardisation in diagnosis can be provided by the results of an international online survey assessing the prevalence and diagnosis of VAT in 288 intensive care units in Latin American and Western European countries, published in 2014. According to them, as many as 79.2% of the wards surveyed reported that they base the diagnosis of VAT on clinical and microbiological criteria, while 13.9% base it based on symptoms alone [10]. In the following paragraphs, we have attempted to collate together the diagnostic criteria collected in the literature to enable easier diagnostic management of mechanically ventilated patients.

Radiological diagnosis

The importance of VAT is the absence of new infiltrates in the lung parenchyma, otherwise this criterion becomes characteristic of VAP [2, 5]. The only non-uniform issue seems to be the type of test performed. In a multicentre cohort study of emergency department (ED) patients, CXR (chest-X-ray) and CT (computed tomography) were compared for the diagnosis of pulmonary opacities and it was found that reliance on CXR can result in a significant rates of misdiagnosis [6]. However, CT also has its limitations, as evidenced by a study showing that in-hospital transport of mechanically ventilated patients, in our consideration for CT, is a risk factor for the development of VAP [7]. Recently, lung ultrasound has shown increasing promise in detecting early infiltrates [8,9].The results of the aforementioned international online survey [10] showed that in 49.2% of the departments surveyed, CT is never used for diagnosis and 48.3% only when the CXR result is inconclusive. Therefore, supporting the general trend in clinical practice, CXR appears to be the first choice in radiological diagnosis to exclude new infiltrates in lung tissue. In addition to the mentioned absence of new inflammatory infiltrates on CXR/CT, clinical and microbiological criteria must be completed to make the diagnosis [5].

Clinical presentation

In order to diagnose VAT, it is first necessary to determine ventilator-associated condition - VAC (increase in daily minimum PEEP of ≥ 3 cm of H_2O or by FIO_2 > 0.2 sustained for at least 2 days) [5]. Of the clinical symptoms, at least one of the following two must be confirmed [2]:

- Temperature >38ºC
- Leukocytosis >12000/mm^3 or leukopenia < 4000/mm^3 as well as at least one of the following 3:
- Initiation of purulent secretion or change in suction requirements
- Increase in oxygen requirements (expressed as an increase in FiO_2 or the PaO_2 /FiO_2 ratio)
- Clinical pulmonary infection score (CPIS) ≥ 6.

Microbiological diagnosis and analysis of respiratory tract aspirate

Including the criteria listed in the paragraph above, there must be a positive microbiological culture from material taken a minimum of 24 h after the last antibiotic dose, if antibiotic therapy is used [2]. The most common material among the departments surveyed (59.4%) is endotracheal aspirate (EA) [10]. A result that argues for ongoing infection (VARI – ventilator-associated respiratory infection) rather than bacterial colonization is the demonstration of many polymorphonuclear leukocytes (PMNL) and many bacteria. Culture of EA must reach at least 10^5 cfu/mL. Material can also be collected bronchoscopically in the form of bronchoalveolar lavage (B-BAL) or as a protected specimen brush (PSB) technique. To confirm infection Cytospin test must show several PMNL and without bacteria, B-BAL <10^4 cfu/mL or PSB<10^3 cfu/mL. For testing, could be also used non-bronchoscopic BAL (N-BAL), then results as a few PMNL and no bacteria (Cytospin), N-BAL: <10^3cfu/mL are considered positive for infection. Regardless of the method, it is important to remember that the patient must not be critically ill and cultures were not performed within 24 to 48h [2, 5].

The inflammatory markers

Certain inflammatory biomarkers like CRP (C-reactive protein) and PCT (procalcitonine) may be useful in the additional evaluation of patients with ventilator-associated respiratory infections (VARI). In VAT patients, CRP seems to be particularly useful, as its values increase according to analyses in VAP as well as VAT patients, while the usefulness of PCT is rather limited to the VAP group [5]. However, more recent multicenter study has shown that both markers were elevated in both groups of patients, but significantly more in VAP patients compared to VAT patients. Therefore, the authors negated their usefulness in differentiating the two disease entities [11].

VAT - TREATMENT AND PREVENTION

Role and significance of antibiotic therapy

Only half of the respondents (50.3%) of the online VAT survey [10] agreed that patients should receive antibiotic therapy, nearly 1/4 of the surveyed departments routinely included antibiotic therapy and 42% only in cases of hemodynamic instability. In contrast, according to 26% of respondents, VAT should not be treated with antibiotic therapy. Chemotherapeutics were turned on by most departments (73.3%) within 12 hours of diagnosis. There is still no complete consensus in the literature about the therapeutic efficacy of the included antibiotic therapy. On the other hand, many authors believe that such therapeutic management contributes to inhibition of the progression of VAT to VAP [4, 12-14]. According to a multicenter study [9], proper antibiotic therapy for VAT is crucial, and appropriate antibiotic therapy is independently associated with a reduced risk of subsequent VAP (only 13.9% of VAT patients developed VAP). Also, the appropriate choice of antibiotics provides cost-effectiveness and limits the development of resistance in bacteria, while inappropriate treatment is associated with poorer outcomes in VAT patients. Although the authors' results did not show statistical significance to support a

Table 1. Potential benefits and risks of antibiotic therapy in the VAT treatment process.

The potential benefits and risks of antibiotic therapy in the therapeutic process of VAT mentioned in the literature	
Benefits associated with antibiotic therapy	Risks associated with antibiotic therapy
Reduction of the VAT to VAP progression	Adverse effects of antibiotics
Reduction in mortality	Absence of evident benefits of antibiotic therapy in the literature
Reduction in duration of mechanical ventilation	Adverse financial issues*
Shorter length of ICU hospitalisation	Risk of development of multidrug-resistant strains*
Reduction in the cost of further treatment*	
Reduction in the possibility of developing antibiotic resistance among bacteria*	

* These discrepancies in the literature are due to the choice of different antibiotics, their forms of administration and the length of treatment, which is a result of diagnostic difficulties and the inconsistent definition of VAT. It is therefore important to be aware that the way in which antibiotic therapy is administered and the clinical picture of the patient may be crucial.

positive effect of treatment on the reduction of mortality, shorter duration of mechanical ventilation, or ICU stay, which would be the result of VAT morbidity inhibition, we can also find reports in the literature confirming the positive effect of antibiotic therapy on the aforementioned issues [12, 14, 15]. On the other hand, there are certain limitations to the introduction of treatments, so the medical community is still not sure about the validity or effectiveness of treating all cases of patients. The main reason for this is the continued difficulties in diagnosis and inconsistencies in the definition of VAT. Guidelines from Infectious Diseases Society of America (IDSA) suggest that antibiotic therapy should not be routinely included in cases of VAT, despite shortening the duration of mechanical ventilation. This indication is based on the lack of clear benefit in the literature, financial issues, antibiotic toxicity or the risk of multidrug-resistant bacteria [16]. The inclusion of antibiotic therapy should therefore be based on an individual analysis of the patient's clinical picture, where the recommended indications for antibiotics is VAT complicated by septic shock or oxygen deficiency [3, 16]. However, it is important to be aware of the deficiency of adequate research at the time the above recommendations were prepared. The duration of antibiotic therapy is also important in the context of the problem of the development of multidrug-resistant strains and the subsequent development of VAP [4]. Respondents to the previously cited online survey at 66.7% used antibiotic therapy between 7 and 10 days. Only 24% of respondents administered antibiotics for less than 7 days. Half of the surveyed wards decide to de-escalate therapy when microbiological culture results are available. In surveyed departments from European countries, 3rd generation cephalosporins were used most often [10]. Another important issue is the form of antibiotics administered. The most common model of antibiotic therapy was intravenous antibiotic therapy - used in 62.5% of the ICUs surveyed (published in 2014). For intravenous forms, nebulization formulations were included as monotherapy and combinations by 9.4% and 5.6% of wards, respectively. Only 2.1% admitted to administering drugs only by nebulization [10]. In 2017, the European Society for Clinical Microbiology and Infectious Diseases (ESCMID) recommended avoiding the use of nebulized antibiotics as monotherapy or adjuvant to intravenous forms in VAT patients due to safety concerns and weak evidence in terms of their potential benefits [17]. Despite this, and in contrast to previous results [10], in a global survey conducted in 2017 concerning the use of aerosol forms of antibiotics in mechanically ventilated patients, in which 410 units participated, only 26.8% of them reported that they did not use nebulized antibiotics. Moreover, as many as 49.4% of the surveyed units used them in the context of VAT [18]. The use of this form of antibiotic allows to achieve a higher desired concentration of the drug in the respiratory tract, reducing its systemic concentration and, consequently, its side effects. In addition, importantly, they show a positive effect on the eradication of multidrug-resistant bacteria and reduce the emergence of new resistances. In the context of VAT, they reduce the incidence of VAP and facilitate the transition away from mechanical ventilation [19]. To conclusively resolve the use of antibiotics in nebulization both as monotherapy and as an adjuvant to systemic treatment, further studies are required. Based on the paragraph above, the potential benefits and risks of antibiotic therapy in the VAT treatment process are listed in the table 1.

Methods to prevent the development of VAT

Preventing new cases of VAT in hospital wards remains an especially important issue. It is evident that the basic preventive measures to protect against other nosocomial infections is to minimize the transmission of nosocomial pathogens through the frequent use of disinfectants, disposable personal protective equipment every time a patients contact, or isolation of septic patients. A study was conducted [20] that demonstrated

the effectiveness of implementing a care package to prevent ventilator-associated infections in terms of preventing VAT in paediatric patients. The above package consisted of: raising the head of the bed to at least 30 degrees, rinsing the mouth with chlorhexidine solution at least every 4 hours, extubating as early as possible, suctioning oral secretions before each intubation (with a separate oral catheter, using closed systems for suctioning), or using hand hygiene between contact with patients, which is of course a fundamental procedure, not only in the context of respiratory infections. Implementation of the package resulted in a 53% reduction in the VAT rate for over 18 months in the pediatric ICU (PICU) where the study was conducted. Other authors focusing on methods of preventing ventilator-associated infections [21], report that minimizing sedation by avoiding high doses of benzodiazepines and replacing them with other agents (analgesics, propofol, dexmedetomidine, possibly antipsychotics) when possible may also be helpful in the context of VAT prevention. In addition, in the absence of contraindications, spontaneous awakening or daily breaks in sedation should be attempted. This is to reduce the average duration of ventilator therapy. Early mobilization of the patient may also prove beneficial. In contrast, decontamination of the gastrointestinal tract is not helpful in preventing VAT.

VAT AND VAP DIFFERENTIATION

An important issue in treatment is differentiating VAT and VAP. Ventilator-associated pneumonia (VAP) is defined as pneumonia that occurs 48-72 hours or later after endotracheal intubation. It is a much better understood disease entity than VAT, and consequently, many more studies and publications on VAP are available. The hallmarks of VAP are the presence of a new or progressive infiltrate, fever, increased white blood cell count, and changes in sputum characteristics. According to estimates, VAP occurs in 9-27% of all mechanically ventilated patients, making it the most common infection in mechanically ventilated patients and the second most common nosocomial infection in the intensive care unit. On average, VAP develops 3.3 days after intubation [24]. VAP is associated with serious consequences for adult, endotracheally intubated patients and leads to an increase in patient mortality, which is approximately 20-50% [2]. In contrast, another source reports a mortality rate of 9-13 [24]. VAT is believed to be an intermediate stage between lower airway colonization and VAP [10]. The study found that in one-third of patients VAT progressed to VAP [22], and many other authors believe that properly selected antibiotic therapy prevents the development of VAP, as further explained in this article [4, 12-14]. Differentiating VAT and VAP is sometimes complicated and requires a lot of experience on the part of the treating physician. This is because the clinical manifestations can be very similar, and the only clear difference is the presence of a persistent infiltrate on the chest X-ray of a patient with VAP [2, 22]. Other changes in the radiograph of a patient with VAP may be consolidation or cavitation, not present in VAT. Radiologic evaluation will not always allow a confident diagnosis, as it may be complicated by the presence of previous infiltration of lung tissue, severe congestive heart failure or the appearance of acute respiratory distress syndrome (ARDS) [2]. A CT scan would be helpful in this case, but transporting a patient to the radiology department is associated with a significant increase in the incidence of VAP among transported patients [5]. Lung ultrasound can also be considered a promising method to distinguish VAT from VAP, but its usefulness remains limited by poor reproducibility and the need for extensive experience in performing and interpreting this test [23]. Differentiating VAT and VAP episodes in patients with COPD can also be complicated because changes are present in the initial radiographic findings, making it difficult to identify newly formed or progressive infiltrates. The future of effectively differentiating VAT and VAP in patients with COPD may also lie in the use of computed tomography or lung ultrasonography [5]. Another difference between VAT and VAP is the distinctiveness of the microbiological examination. Differences are present only in cultures of materials collected using the PSB technique and bronchoalveolar lavage (B-BAL and N-BAL) - results that exceed the upper diagnostic limits for VAT, mentioned in the previous paragraph, are diagnostic for VAP. The cytospin method for VAP shows a lot of polymorphonuclear leukocytes (PMNL) and bacteria. Microbiological testing of endotracheal aspirate (EA), on the other hand, will not be diagnostic in this case, as the results are similar in patients with VAT and VAP [2].

VAT IN COPD, COVID AND CRITICALLY ILL PATIENT GROUP

Mechanical ventilation itself already carries the risk of complications that include VAT. However, there are cases in which these risks are significantly increased. This paragraph focuses on patients with chronic obstructive pulmonary disease (COPD), COVID-19 and emergency conditions.

VAT and COPD

Mechanically ventilated COPD patients are described first. The study of 2960 mechanically ventilated adult patients compared patients with COPD (n = 494) with patients without COPD (n = 2466). There was no significant relationship (13% versus 10%, p = 0.093) between the incidence of VAT in patients with and without COPD. Moreover, COPD was shown not to be among the risk factors for progression from VAT to VAP. Among patients with ventilator-associated lower respiratory tract inflammation, infections with *E. Coli* and *S. Maltophilia* occurred at a significantly higher frequency in patients with COPD compared to patients without COPD. In contrast, MDR bacterial infections occurred with similar frequency in both study groups. Upon further analysis, patients with COPD who developed VAT had a significantly longer

duration of mechanical ventilation and thus required a much longer stay in the ICU compared to patients without ventilator-associated tracheobronchitis [25]. Similar results were obtained in another study conducted on 81 case-control pairs. It was shown that the group of COPD patients with lower respiratory tract infections caused by mechanical ventilation required a significantly longer stay in the intensive care unit combined with ventilator therapy. It was also detected that the number of new bacterial strains in patients with positive tracheal aspirate was significantly higher in COPD patients than in the control group [26]. A completely different conclusion can be drawn from a study by Nseir et al. [2]. They found that VAT patients, compared to controls, had significantly lower median days of mechanical ventilation and had to be hospitalized longer in the ICU, but antibiotic therapy did not appear to protect against VAP [2].

VAT in critically ill patients

The situation is similar among patients admitted to the ICU in critical condition. Seventy-six patients with VAT were admitted to the study, with no significant differences in reasons for admission or comorbidities. VAT patients required a longer ICU hospitalization (median 22 days) compared to the control group (median 15 days). They also needed longer ventilator therapy (median 18 days) relative to the control group (median 9 days). In contrast, total length of hospitalization and in-hospital mortality was very similar in both groups of patients [27]. The results are similar in other studies, namely the median time to ICU discharge for those with VAT was 21 days, while in the group without ventilator-associated lower respiratory tract infections, it was 12 days [12]. The incidence of VAT varies in certain groups of critically ill patients. it is higher in the group of neurocritical patients (28.5% vs. 14.1%), but as in the previous case, it is not associated with increased mortality [28].

Potential association between VAT and COVID-19 infection

An additional problem that physicians have been facing for several years is COVID-19. No sufficiently detailed literature has been found on the impact of COVID-19 on VAT, but a multicenter study [29,30] examined ventilator-associated lower respiratory tract infections (VA-LRTI), which includes both VAT and VAP. The study showed that the incidence of VA-LRTI is significantly higher in patients with SARS-CoV-2 virus infection compared to patients infected with influenza virus or without viral infection on ICU admission. The most significant reasons for this relationship were longer mechanical ventilation time, higher incidence of ARDS and administration of higher doses of immunosuppressive drugs to patients with SARS-CoV-2 infection [29, 30]. During the second wave of the pandemic, the recumbent position was frequently used, which was later found to increase the incidence of VA-LRTI [31]. Although the study was not conducted only for VAT, we may be inclined to believe that ongoing COVID-19 infection is a factor in the increased risk of disease. It is noteworthy that patients with severe COVID-19 complicated by VAP had a higher mortality rate, while VAT was not associated with higher in-hospital mortality than in the control group [30]. Progression of VAT to VAP was diagnosed in the vast minority of patients (12.6%) [29].

CONCLUSIONS

Although ventilator-associated tracheobronchitis has been a misunderstood topic for years, with a still uncertain definition, aspects related to pathogenesis, clinical manifestations or microbiological diagnosis seem to be standardized. A controversial issue in diagnosis seems to be the best imaging method to exclude new pulmonary infiltrates. Neither chest X-ray nor lung CT are ideal imaging modalities in this clinical context. This is an important aspect in the context of differentiating VAT from VAP, which is important because much of the medical community considers, this disease entity, to be a condition preceding VAP. This would enable early intervention with properly selected antibiotic therapy, which, supported by many studies, would avoid progression to VAP. Less obvious benefits of antibiotic therapy are its effect on mortality, shorter duration of mechanical ventilation, or patient stays in intensive care units. Further research is also needed to unify the indications for antibiotic inclusion, the forms of drugs administered, and the length of therapy to prevent the emergence of antibiotic resistance. On the other hand, there is no doubt about the validity of taking preventive measures to protect against VAT. Critically ill patients and those with coexisting respiratory diseases such as COPD or COVID-19 infection, according to the available literature, are at risk of longer hospitalization in intensive care units, but further clinical observations are needed understand the aforementioned conditions and other comorbidities affect VAT incidence, progression to VAP and patient prognosis. It should also be noted that many of the studies used in the development of the above article were not conducted with VAT in the lead role. Certainly, further research needs to be done to enable the development of knowledge on the prevention and treatment of patients with VAT and a more complete understanding of the impact of multimorbidity on this disease entity. This will result in improved safety and more effective interventions in mechanically ventilated patients with ongoing respiratory infections.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

ADDRESS FOR CORRESPONDENCE

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REVIEW ARTICLE

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Novel ways of applying artificial intelligence in emergency medicine – literature review

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ABSTRACT

Artificial intelligence (AI) holds immense promise for revolutionizing emergency medicine, expediting diagnosis and treatment decisions. This review explores AI's wide-ranging applications in emergency care, ranging from managing out-of-hospital cardiac arrest (OHCA) to diagnosing fractures, spine injuries, stroke, and pulmonary embolisms, and even assisting in search and rescue missions with snake robots. In OHCA cases, AI aids in early detection, survival prediction, and ECG waveform classification, bolstering prehospital care efficiency. AI-powered digital assistants like the AI4EMS platform optimize diagnosis and patient prioritization, reducing overlooked cases of cardiac arrest and improving response times. Furthermore, AI algorithms enhance the diagnosis of conditions such as pneumothorax, pulmonary emphysema, and fractures by analysing medical images with exceptional accuracy, often outperforming human experts. In stroke and pulmonary embolism, AI expedites diagnosis through automated imaging analysis, enabling swift treatment. AI may enhance triage methods with independent systems, improving patient sharing and treatment quality while minimizing infection risks, especially during pandemics. Medical professionals generally welcome AI triage systems, acknowledging their potential to enhance healthcare efficiency. It is important to understand the scope of development of AI in order to make its application beneficial.

KEY WORDS

AI, triage, diagnosis, emergency

INTRODUCTION

In the field of emergency medicine, where every second can decide a patient's life, advanced technologies based on artificial intelligence are attracting more and more attention. In this context, Artificial intelligence (AI) is becoming a promising tool that can support doctors in quickly interpreting symptoms and making accurate diagnostic decisions. AI does not have one universally accepted definition but is usually described as a research area focusing on the analysis of computer systems capable of solving tasks that require the use of human intelligence. Therefore, we can establish that AI is a set of sciences rather than a discipline itself. This technology draws inspiration from the natural cognitive processes and functions occurring in the human brain. It aims to create a computer system that works like human intelligence [1].

Thanks to the ability to quickly analyse large data sets, AI can help identify rare diseases, interpret laboratory test results, and generate therapeutic proposals. Additionally, the ability to interact with patients in real-time can facilitate the collection of relevant information about their health status and disease history, which is crucial in emergency cases [2].

AI methods are revolutionizing the diagnosis of fractures, enabling the rapid detection of even unusual and difficult to access cases, which significantly reduces the risk of missing them in patients with multiple injuries or after a serious injury. It is an important tool supporting the work of rescuers, making it easier to make the right decisions and further treatment of the patient before reaching the hospital [3].

One of the most important aspects of AI is deep learning. Deep learning is a type of advanced machine learning that uses neural networks to process and analyse large amounts of data. These neural networks are organized into several layers that detect progressively more complex patterns and features in the data. Deep learning can be used for a variety of tasks, such as image classification, speech recognition, language translation, text analysis, and even medical diagnosis. Due to the ability to automatically detect and learn from large data sets, deep learning has become a promising tool in the development of artificial intelligence in medicine [4].

In the medical field, GPT-based chatbots can be used to shorten conversations with patients, aid in disease diagnosis, suggest treatments, and provide medical education [5].

AIM

This paper examines a range of potential applications of AI in emergency medicine analysis, both in established and novel contexts.

REVIEW AND DISCUSSION

OUT-OF-HOSPITAL CARDIAC ARREST

The use of AI to support the early care of patients with out-of-hospital cardiac arrest (OHCA) has received increasing interest in recent years, with a significant increase in research since 2019.

In a review by Toy et al. of 173 cases, in 54 (31%), AI showed a beneficial effect on diagnosis. The main areas of AI application are the classification of electrocardiogram (ECG) results, early detection at the control room level and prediction of survival outcomes. Three main categories of research using AI in out-of-hospital care have been identified: early detection of OHCA, prediction of return of spontaneous circulation (ROSC) and survival, and classification of ECG waveforms. The dynamic nature of prehospital conditions requires rapid data analysis and prediction of outcomes, potentially increasing the effectiveness of out-of-hospital care [6].

Al-Dury et al. used machine learning techniques to confirm that the main predictors of survival in OHCA are initial rhythm, age, time to start cardiopulmonary resuscitation, duration of EMS response, and location of out-of-hospital cardiac arrest. It is worth noting that some traditional factors, such as gender, have shown minimal significance in predicting survival outcomes [7].

Elola et al. developed two architectures of deep neural networks designed to detect the heart rate during out-of-hospital cardiac arrest using short ECG segments. These architectures classify rhythms according to their pulseless electrical activity or pulse-generating rhythm. This ECG-based solution, which can be adapted to any defibrillator/monitor, offers a promising opportunity to improve the accuracy of pulse detection during OHCA, potentially reducing interruptions in chest compressions and improving patient outcomes [8].

A significant proportion of OHCA cases remain undiagnosed during a telephone conversation with a medical dispatcher. Most people are unable to effectively communicate the seriousness of the situation to a rescuer. Rafi et al. developed a machine learning system to recognize OHCA cases based on the phonetic characteristics of callers' voices. The study analysed data from emergency calls to a call centre in Rennes, France, between 2017 and 2019. AI was used to extract predictor variables through computer-automated phonetic analysis, including fundamental frequency, formants, intensity, and various vocal parameters. Integration of these acoustic parameters into decision support systems can improve early recognition and response to OHCA, thereby potentially improving patient outcomes [9].

AI4EMS PROJECT

A voice-controlled digital assistant has been created to help diagnose and prioritize patients in emergencies. The abbreviation AI4EMS is an acronym for Artificial intelligence for Emergency medical services. The AI4EMS platform uses machine learning techniques to recognize symptoms, supporting medics in making the right decisions. This technology is based on algorithms developed based on thousands of medical interviews. Data collected by Danish paramedics shows that AI4EMS software can recognize cardiac arrest within 44 seconds, recognize symptoms 25% faster than humans, and reduce the number of undetected cardiac arrests by 43%. By integrating speech recognition and machine learning technologies, the AI4EMS platform enables real-time analysis of emergency calls and helps assess the problem based on available parameters [10].

Using AI, specifically real-time natural language processing, AI4EMS software actively analyses call content, helping call takers recognize signs of serious illness, such as cardiac arrest. The developed algorithms are based on extensive data from previous medical interviews and look for patterns of verbal and non-verbal communication, including conversational tone and breathing signs [11].

DIAGNOSIS OF PNEUMOTHORAX

CheXNeXt deep learning algorithm demonstrates effectiveness comparable to radiology specialists in identifying various chest pathologies based on chest radiographs. These technological advances hold promise for improving healthcare delivery by potentially increasing the accuracy of interpretation of chest X-rays. Successful implementation of such advances in real-world clinical settings requires further clinical trials in diverse populations [12].

Hong et al. examined the effectiveness of a deep learning-based computer-aided detection (CAD) system in improving the detection of pneumothorax on chest radiographs after percutaneous transthoracic needle biopsy. The study compared the diagnostic accuracy of chest radiographs interpreted using CAD with those interpreted without CAD. The results indicated that the CAD group showed higher sensitivity, negative predictive value, and overall accuracy compared to the non-CAD group. Increased sensitivity was detected in the diagnosis of less extensive pneumothorax (<10% and 10%-15%) in the CAD group. A lower percentage of patients in the CAD group required subsequent drainage catheter placement, suggesting a potential clinical benefit of the CAD system in reducing unnecessary interventions [13].

A meta-analysis by Sugibayashi et al. assessed the effectiveness of deep learning (DL) models in diagnosing pneumothorax and compared it with physician competence. The analysis shows that DLs and physicians have comparable accuracy in detecting pneumothorax on chest radiographs. DL showed a pooled sensitivity of 84% and specificity of 96%, and physicians showed slightly higher sensitivity (85%) and specificity (98%). The study also explored the potential clinical applications of DL diagnostics, such as patient triage and judgment, highlighting its role in improving the speed and accuracy of pneumothorax detection, particularly in emergency departments and intensive care units [14].

Kim et al. used a deep learning approach to classify lung diseases on chest radiographs, aiming to increase

the efficiency and accuracy of computer diagnostic systems. Research conducted on datasets from the US National Institutes of Health and Cheonan University Hospital Soonchunhyang shows promising results in verifying diseases including pneumonia, pneumothorax, and tuberculosis. The authors emphasize the potential of deep learning techniques to revolutionize the diagnosis of lung diseases in X-ray images, emphasizing the importance of data augmentation and learning in achieving the accuracy of computer diagnosis [15]. Studies suggest that the implementation of a deep learning-based CAD system can improve the detection of pneumothorax on chest radiographs after lung biopsy procedures [12, 13, 14, 15].

AI TRIAGE

The AI triage method works independently and replaces classic rescue triage thanks to the use of artificial intelligence. This solution improves the efficiency of patient sharing, streamlining, and speeding up help for those most in need, and reduces the burden on paramedics. Additionally, by shortening patients' waiting time, this method improves the quality of treatment through an individual approach to each patient. During the pandemic, AI triage additionally reduced the risk of contact infections [16].

The results of surveys among medical staff showed that almost half of respondents preferred only AI triage (45.2%), about one third expressed acceptance of both AI triage and classic triage (31.9%), and 22.9% of respondents preferred only classic triage. The overall acceptance rate of AI triage was 77.1%, which indicates the positive response of medical staff to this solution [17].

The introduction of the AI triage method can bring significant benefits to the healthcare system, improving operational efficiency, shortening patient waiting times, and minimizing the risk of infections, especially during crisis periods such as a pandemic. However, it is important to constantly monitor and improve this solution to ensure its effectiveness and compliance with the needs of patients and medical staff [18, 19].

DIAGNOSIS OF PULMONARY EMPHYSEMA

Nagaraj at al. presented automatic deep learning based on minimum intensity projection (minIP) low-dose computed tomography (LDCT) images for the classification and detection of pulmonary emphysema. Using minIP as a specific diagnostic technique, the unsupervised DL algorithm can effectively diagnose atypical cases commonly encountered in LDCT screening for lung cancer [20].

The main causes of emphysema are smoking or α -1-antitrypsin deficiency. Diagnosis of this condition relies mainly on imaging. An automated emphysema quantifier based on AI supports this. This perfectly correlates with the Tiffeneau index, based on spirometry results. Thanks to this, it can be effectively used for diagnosis, staging and monitoring patients for long periods [21].

It is worth noting that emphysema can lead to significant impairment of lung function, which affects the quality of life of patients. The introduction of an automated tool based on AI can significantly facilitate and speed up the diagnosis process and help patients have faster access to appropriate treatment. However, there is a need for continuous improvement of this tool to ensure its effectiveness and compliance with the latest medical standards [22].

There is great interest in developing methods to automatically distinguish COPD from healthy people. Ahmed et al. discuss a 3D deep learning technique for classifying COPD and emphysema based solely on volume annotations. They demonstrated the impact of transfer learning on the classification of emphysema, using knowledge transferred from a previously trained model for the classification of COPD [23].

FRACTURE DIAGNOSIS

AI methods enable quick detection of fractures in unusual and hard-to-find locations, which significantly reduces the risk of missing a fracture in patients with multiple injuries or after massive trauma. This helps rescuers work efficiently, make decisions and further deal with the patient before reaching the hospital. The most used AI method was convolutional neural networks (CNN). The accuracy of fracture identification in the seven studies ranged from 83 to 98. The most used AI method in diagnosing fractures is CNN, which are characterized by high efficiency and accuracy. Accuracy in identifying fractures in seven studies ranged from 83 to 98 percent, demonstrating the potential of these tools in detecting injuries [24].

Thanks to the use of AI, doctors and paramedics can quickly and precisely identify any fractures, even those that are difficult to identify clinically. This allows for faster decisions to be made regarding further treatment, including possible stabilization of the patient and preparation for transport. This eliminates the risk of delays in aiding and enables quick intervention in cases where time is crucial for the treatment outcome [25].

The introduction of AI methods for fracture diagnosis brings significant benefits for patients, rescuers, and medical staff, improving the efficiency and precision of diagnosis and contributing to faster and more effective treatment of injuries [26].

SPINE INJURIES

The use of AI enables rapid and automated diagnosis of cervical spine injuries and rapid assessment of vertebral compression fractures. Thanks to AI algorithms that analyse images from radiological examinations, doctors can effectively identify potential cervical spine injuries, which significantly speeds up the diagnosis process. In the case of severe spinal injuries, such as vertebral compression fractures, prompt evaluation is crucial to immediately implement appropriate treatment and minimize the risk of complications. AI also enables the detection of subtle de-

tails in imaging tests that may be difficult for humans to see, leading to more precise injury diagnosis [27].

Automating this process allows doctors to focus on interpreting results and making therapeutic decisions, instead of wasting time manually analysing each image. Additionally, AI can be used to predict complications and assess the risk associated with cervical spine injuries. Thanks to machine learning and the analysis of large clinical data sets, AI can identify prognostic factors and support doctors in making decisions regarding further therapeutic procedures. As a result, the use of AI in the diagnosis and treatment of cervical spine injuries contributes to shortening the time needed for assessment and therapy planning, which may be important for patients, especially in the case of sudden and serious spine injuries [28, 29].

STROKE

Stroke patients require immediate clinical and imaging assessment to ensure rapid assistance and implementation of treatment procedures. AI methods accelerate and improve acute stroke imaging, significantly increasing the efficiency and accuracy of stroke diagnosis. Particularly in the case of stroke, time is of the essence, and fast and precise imaging can be crucial for the effectiveness of treatment [26]. AI-based technologies, such as image processing algorithms and neural networks, can automatically analyse computed tomography or magnetic resonance imaging images, helping doctors identify damaged areas and assess the extent of a stroke. Additionally, AI can be used to detect large vessel occlusions on computed tomography angiograms, which can quickly identify patients eligible for recanalization therapy, such as thrombolysis or mechanical thrombectomy. The use of AI in stroke diagnosis not only speeds up the diagnosis process but can also contribute to reducing the risk of complications and improving clinical outcomes through quick and targeted implementation of appropriate treatment [30].

AI technology is widely used in acute stroke imaging, including both ischemic and haemorrhagic subtypes, where early identification plays a key role in initiating timely interventions to reduce morbidity and mortality; assists in many aspects of stroke management, including the detection and segmentation of infarcts or haemorrhages, classification, identification of large vessel occlusions, early assessment of the Alberta Stroke Program early computed tomography score and prognosis, and new techniques such as convolutional neural networks are very promising to perform these imaging-based tasks efficiently and accurately [31, 32].

PULMONARY EMBOLISM

AI methods prove to be extremely helpful in cases of acute pulmonary embolism. Currently, three programs are available that not only detect pulmonary embolism but also perform computed tomography angiograms of the pulmonary arteries. Thanks to this, it is possible to make a quick diagnosis and efficiently triage patients. Analyses of the performance of these AI methods in the case of pulmonary embolism show high sensitivity and specificity, reaching up to 85% [33].

Additionally, these programs have additional features, such as allowing emergency team members to access patient test results and allowing clinicians to view key images from angiograms demonstrating clots. Thanks to this, paramedics can quickly make decisions based on test results, and doctors have easy access to important information, which speeds up the diagnostic process and therapeutic decision-making [34].

The use of AI in the diagnosis of pulmonary embolism brings significant benefits, improving the efficiency and accuracy of diagnosis and enabling rapid medical intervention. These advanced tools can significantly improve patient clinical outcomes, especially in emergency cases where time is of the essence. However, continuous improvement and monitoring of these methods is necessary to ensure their effectiveness and compliance with the latest medical standards [35].

SNAKEBOTS

A slightly different aspect of emergency medicine in which AI can be used is in dangerous rescue search and rescue operations. Snake robots, equipped with sensors, can be used to transport tools to areas that are dangerous or inaccessible to humans, removing the need for direct human intervention [36]. People in critical situations receive support through SAR operations, but these activities are difficult and dangerous even for experienced rescuers. Therefore, there is an increased interest in using technology to minimize the risk for both victims and rescuers [37].

Snake robots can operate as multi-agent systems, which gives them high flexibility and adaptability. They are also able to use existing infrastructure for movement. Thanks to different gait patterns, snake robots can perform a variety of tasks without the need for additional modifications. Their modular structure allows them to be adapted to various means of transport, which makes them versatile in rescue operations [38].

Snake robots are a promising choice due to their robust construction and resilience in rescue operations. Additionally, they can be equipped with sensors and cameras that enable the assessment of the condition of people in danger and provide rescuers with environmental data in real-time. This data can be analyzed by AI, allowing a comprehensive plan of action to be generated in a matter of minutes. AI can also analyze various rescue options and choose the best course of action, tailored to the situation. This allows you to quickly identify threats and make informed decisions during a rescue operation [39, 40].

CONCLUSIONS

The integration of artificial intelligence (AI) into emergency medicine has demonstrated remarkable po-

tential to revolutionize various aspects of patient care and rescue operations. From the rapid diagnosis of life-threatening conditions such as out-of-hospital cardiac arrest (OHCA) and pulmonary embolism to the precise identification of fractures, spinal injuries, and strokes, AI technologies have significantly enhanced the efficiency, accuracy, and speed of medical interventions. Moreover, AI-driven solutions like AI triage methods have not only optimized patient prioritization and resource allocation but also minimized the risk of infections, particularly during crises like pandemics. The advancements in AI, particularly in deep learning algorithms, have enabled the development of sophisticated tools capable of analyzing complex medical data sets, interpreting imaging studies, and predicting clinical outcomes with high precision. Furthermore, the utilization of AI extends beyond traditional diagnostic modalities, encompassing innovative applications such as snake robots in search and rescue operations, where AI-driven analysis facilitates swift decision-making and ensures the safety of both rescuers and victims. However, while AI presents immense opportunities for enhancing emergency medical care, ongoing monitoring, refinement, and adherence to medical standards are essential to maximize its effectiveness and ensure patient safety. Continued research and collaboration between healthcare professionals, technologists, and regulatory bodies are crucial for harnessing the full potential of AI in emergency medicine while addressing challenges such as data privacy, algorithm biases, and ethical considerations.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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CASE REPORT

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Orbitocranial penetrating injury with a lawnmower blade: case report

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ABSTRACT

The aim of this study is to present the management of a patient with orbitocranial penetrating injury by a large foreign body. The case described in the article was taken from the work of the Regional Specialist Hospital No. 5 in Sosnowiec. The patient was hit by a fragment broken off a lawnmower blade. The patient was transported to a district Hospital in Racibórz by the emergency medical team . After performing basic imaging diagnostics and temporary surgical management at another unit, the patient was transported to a multispecialty center for further treatment, where the surgical treatment was applied. A foreign body embedded in the craniofacial region penetrating the orbit and bordering the anterior cranial fossa constitutes a challenging case requiring the cooperation of a team composed of neurosurgeons, otolaryngologists, ophthalmologists, maxillofacial surgeons. The treatment of the patient should be preceded by a thorough analysis of imaging studies.

KEY WORDS

foreign body, trauma, orbit

INTRODUCTION

Injuries resulting from the penetration of a large foreign body into the facial skull are not common, but they can lead to a high percentage of complications that result in death [1]. Due to the proximity of many vital anatomical structures, such injuries require a multidisciplinary approach and cooperation between neurosurgeons, otolaryngologists, ophthalmologists, maxillofacial surgeons, and radiologists. The literature provides many examples of foreign bodies causing penetrating orbital injuries, such as pencils, knives, umbrellas, keys, forks, needles, and arrows [2]. These injuries most often occur as a result of accidents, suicide, or murder attempts [3].

COMPLICATIONS

The most common complications of foreign bodies penetrating the orbit include: visual disturbances including blindness, nerve damage, fractures of the orbit, movement of the foreign body due to eye movement, CSF leaks, cerebral abscesses, and meningitis [4].

The risk of infectious complications increases if the penetrating object is organic, for example, a piece of branch embedded due to its porous structure and the possibility of leaving small fragments undetectable by imaging studies [5, 6].

IMAGING DIAGNOSTICS

Imaging diagnostics are extremely important in this type of injury and allow for the selection of the appropriate treatment method. The standard procedure is to perform a CT scan without contrast. This allows for the assessment of the dimensions of the foreign body and the estimation of tissue damage. In cases where the object is wooden, MRI is helpful as it allows for better differentiation of the object from surrounding tissues [7]. In the event of bleeding or suspicion of vascular damage, angiography is indicated [8].

TREATMENT

Treatment involves surgical removal of the foreign body and antibiotic therapy. Schreckinger et al. recommend initiating antibiotic therapy immediately upon admission [2]. Due to the frequent consequences of the injury such as bone fractures, hemorrhages, vascular damage, CSF leaks, and damage to the visual organ, cooperation with a multidisciplinary team is often necessary.

THE AIM

The aim of this study is to present the management of a patient with orbitocranial penetrating injury by a large foreign body.

THE CASE REPORT

On May 29th at 12:00 PM, the emergency medical team was called to an injury that occurred on the patient's property. While a third party was mowing the lawn, a piece of the lawnmower blade broke off and struck the face of a bystander. The injury did not result in loss of consciousness. The patient was transported to the district hospital in Racibórz, where the entry wound was surgically secured, and the patient received a tetanus antitoxin. PA and lateral skull X-rays were taken, revealing a foreign body within the facial skull, penetrating to the area of the anterior cranial fossa. An ophthalmological examination showed exophthalmos of the right eye, absence of light perception, immobility of the eyeball, and a dilated pupil (Fig. 1-3).

The patient was airlifted by LPR to the emergency department WSS5 in Sosnowiec, where a CT scan of the facial and cranial skull was performed, showing a metallic foreign body measuring 65x14mm extending to the posterior ethmoid, sphenoid sinus, and reshaping the structures of the right orbit. The foreign body was causing damage to the optic nerve and compressing the RICA in the paraclinoid segment. A CT angiography of the cerebral arteries was also performed, confirming the findings of the cranial CT scan. After consultation with a maxillofacial surgeon, otolaryngologist, and neurosurgeon, the patient was transferred to the CTO for multidisciplinary surgical treatment. Surgery began at 21:00. On the right side, the bifurcation of the common carotid artery was dissected, a pterional craniotomy was performed, clinoectomy of the right anterior clinoid process, decompression of the optic nerve and the internal carotid artery in the intracranial segment was achieved, and the artery wall was not damaged. The procedure was assisted by an otolaryngologist and maxillofacial surgeon, who removed the foreign body (Fig.4). Postoperatively, the patient was stable, without apparent new neurological deficits and with a tamponade placed. Due to bleeding from the facial skull and the risk of aspiration, the patient was left intubated and connected to a ventilator. On 05/31/23, the patient was routinely transferred to the ICU, where a control CT was performed on the second day. On the sixth day, IV sedation was discontinued; on the seventh day, the patient was disconnected from the ventilator and extubated. On the tenth day, due to increasing inflammatory parameters, empirical treatment with Meropenem 1 g x10 JM every 8 hours, Vancomycin 500 mg every 6 hours, Gentamicin 80 mg / 2 ml every 24 hours and mannitol 15% 250 ml once a day was initiated. All medications were administered intravenously. The patient was transferred to the Neurosurgical Ward, where antibiotic therapy was gradually continued, achieving a decrease in inflammatory parameters and clinical improvement. During the stay, the patient underwent intensive rehabilitation, and gradual improvement in neurological condition was observed. On 07/12/23, the patient was discharged in good general condition, able to follow

Fig. 1. State at which the patient was transported by the LPR to the ER of the WSS5 in Sosnowiec.

Fig. 2. PA skull X-ray scan.

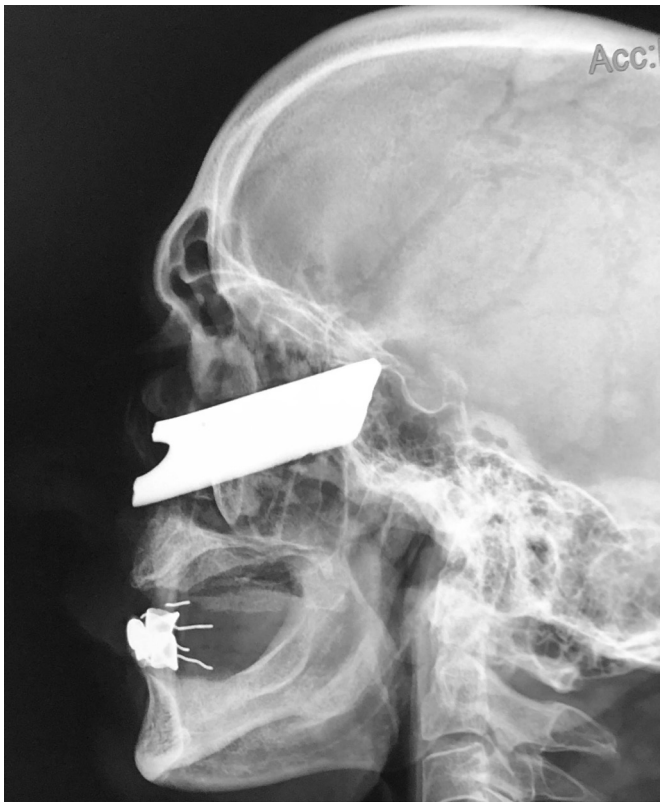

Fig. 3. Lateral X-ray scan.

Fig. 4. Removed lawnmower blade

simple commands. On the day of discharge, there was a left-sided paresis of Lovett scale III/IV. The patient was discharged home and referred to the Neurological Rehabilitation Department.

CONCLUSIONS

Orbitocranial penetrating injuries are a small percentage of all head and neck injuries, yet they are associated with many dangerous consequences. Thorough analysis of radiological examinations and knowledge of anatomy are essential for the proper management of such injuries. In cases of large foreign bodies with significant damage to surrounding tissues, immediate treatment at a trauma center brings measurable benefits and, with the involvement of a multidisciplinary team, allows for limiting functional and aesthetic deficits.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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