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Participation of fire protection units in Poland in ensuring the continuous operation of ventilators for home use — a 7-year observation

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ABSTRACT

Introduction: After each weather front with gales all over Poland, firemen have to perform a few hundred or so interventions. The life of persons covered by a specialistic treatment — home mechanical ventilation HMV — depends upon stable supplies of electricity. In case of breakdowns, indispensable aid is given by firemen who deliver generating sets available in Rescue and Firefighting Units (RFU).

Aim of the study: Analysis and a statistical presentation of interventions of fire protection units to support the correct operation of home medical machines in case of temporary power failure.

Material and methods: Data obtained from the Decision Support System of the State Fire Service (SFS DSS), made available to the authors by the Operational Planning Bureau at the Headquarters of the State Fire Service. In graphical presentations utilized were materials from the Head Office of Geodesy and Cartography, Law on Geodesy and Cartography, viz. Database for Topographic Objects, National Register of Borders. Medical data consistent with the purpose of the study were collected from the analysis of reports compiled by the person in charge of a rescue action of the State Fire Service, which is not the leading service in medical interventions.

Results: In 2015–2021 were 1490 local hazards in which case it was necessary to support the operation — in most cases of ventilators for home use among people requiring ventilator-based therapy. The data show a constantly rising trend, the number of such actions increased by 64.29% — from 163 to 276 [mean (M) = 215.86, standard deviation (SD) = 66.35]. The average waiting time for undertaking intervention in these types of events was 910.68 seconds (15 min, 10 s).

Conclusions: A significant element of rescue actions are volunteer fire brigade squads for being better deployed in rural areas, provided with generating sets; they can ensure faster an emergency electricity source. Persons in charge of a rescue action should draw up the medical part of a report more accurately (concerning the victim and the disease entity) while performing qualified first aid procedures.

Key words: State Fire Service, qualified first aid, spatial information systems, home mechanical ventilation, power failure

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Introduction

Interventions of fire protection units (FPU) during strong winds are mainly associated with the removal of gale effects, like trees felled on roads, walkways, parking lots, securing of torn-off roofs and parts of building facades. After each weather front with gales all over Poland, firemen have to perform a few hundred or so interventions [1]. They consist mainly of

clearing walkways and roads blocked with a felled tree, or boughs which fall upon parked cars, some trees yield to the wind, bend down and rest upon buildings, and some of them disrupt power transmission lines. The last case is particular since it leaves a few hundred or so nearby households without electricity. For most of them, it causes difficulties and discomfort, but there are also some houses in which the real drama happens.

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The life of persons covered by a specialistic treatment — home mechanical ventilation (HMV) — depends upon stable supplies of electricity. In case of breakdowns, indispensable aid is given by firemen who deliver generating sets available in rescue and firefighting units (RFU).

A considerable contribution to such events comes from volunteer fire brigade (VFB) scouts who also support patients using ventilators for home use or oxygen concentrators. The location of VFBs is frequently more convenient in rural areas, too distant to be reached by SFS and National Emergency Medical System (NEMS) [2].

In the events analysed by the authors of the study, a generating set is directly connected with saving lives, although it is not a medical device. Home mechanical ventilation (HMV) is a routine method for treating patients with chronic respiratory failure (CRF). Among its most frequently mentioned causes are nervous-and-muscular diseases and complications after high energy traumas affecting the head or the spine. In the last 20 years, in the developed countries of North America and Europe, there has been observed the development of this method accompanied by increased demand for such a type of therapy [3].

Home mechanical ventilation (HMV) consists in treating CRF with a ventilator *viz.* a machine that either supports or substitutes for a patient's difficulty breathing. Until recently, such devices used to be reserved only for hospitals, mainly for intensive care units (ICU). Nowadays, due to progress in medicine and technology, ventilator treatment may be applicable in home environments.

The manufacturers of ventilators adapt their equipment to the conditions at the patient's home e.g., efficient batteries which should ensure the device's operation in emergencies as long as possible. It is crucial since in patients' houses there is no alternative emergency supply as in the case of medical establishments. Ventilators have become smaller, lighter, reliable and simple to operate. Moreover, elaborated operating procedures allow one to use HMV effectively and safely outside hospitals [4–5].

Among the main HMV goals enumerated are a reduction of symptoms of alveolar hyperventilation, improvement of life comfort, increase in life and professional activity, and enabling patients with CRF to come back home from the hospital. The model of such a type of home care has become so essential and needed that for some years the National Health Fund [NHF] has concluded contracts for services rendered by HMV centres. What is interesting, the Fund does not cover individual financial assistance in purchasing generating sets; hence, so important is the participation of fire protection units (FPU) in an emergency, *viz.* in case of power failures [6–7].

Aim of the study

Analysis and a statistical presentation of interventions of fire protection units (FPU) to support the correct operation of home medical machines in case of temporary power failure.

Materials and methods

In the paper utilized were the data from the Decision Support System of the State Fire Service (SFS DSS), made available to the authors by the Operational Planning Bureau (OPB) at the Headquarters of the State Fire Service (SFS HQ). The materials under analysis cover the years 2015–2021.

Through QGIS geoinformation systems identified and visualized the places in which FPU firemen had to act during temporary power failures and used generating sets to supply respiratory support devices. With some tools for spatial isolation, the average distance between events and the nearest FPU was determined.

In graphical presentations utilized were materials from the Head Office of Geodesy and Cartography (GUGiK), pursuant to art. 40a . 2 point. 1 of Law on Geodesy and Cartography, *viz.* Database for Topographic Objects (BDOT10k), National Register of Borders (PRG) [8–9].

The database was prepared in Microsoft Excel with an MS Office 2016 package for Windows 10. A statistical analysis of the results was performed with STATISTICA 12 (StatSoft Polska). The quantitative data were described according to the form of the distribution of a variable: average and standard deviation (on the condition the distribution complied with the normal distribution). Shapiro-Wilk test was used for checking the conformity with the normal distribution; instead, for examining the relationship among the groups applied was R Spearman correlation. As statistically significant acknowledged were correlations and differences at a significance level of $p < 0.05$.

Results

According to the records kept e.g. by the State Fire Service (SFS), in the years 2015–2021, there were 1490 local hazards (LH) in which case it was necessary to support the operation — in most cases of ventilators for home use among people requiring ventilator-based therapy (Fig.1). The data show a constantly rising trend. In the period under analysis (years 2015–2021), the number of such actions increased by 64.29% — from 163 to 276 ($M = 215.86$, $SD = 66.35$).

The average waiting time for undertaking FPU intervention in these types of events, counted from the

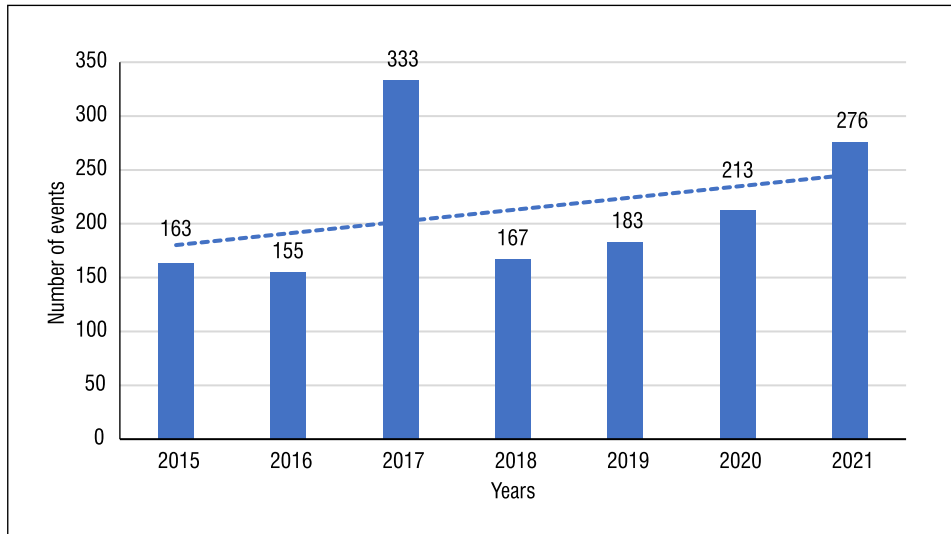


Figure 1. The number of events supporting the proper functioning of home use ventilators in 2015–2021 (Source: own elaboration)

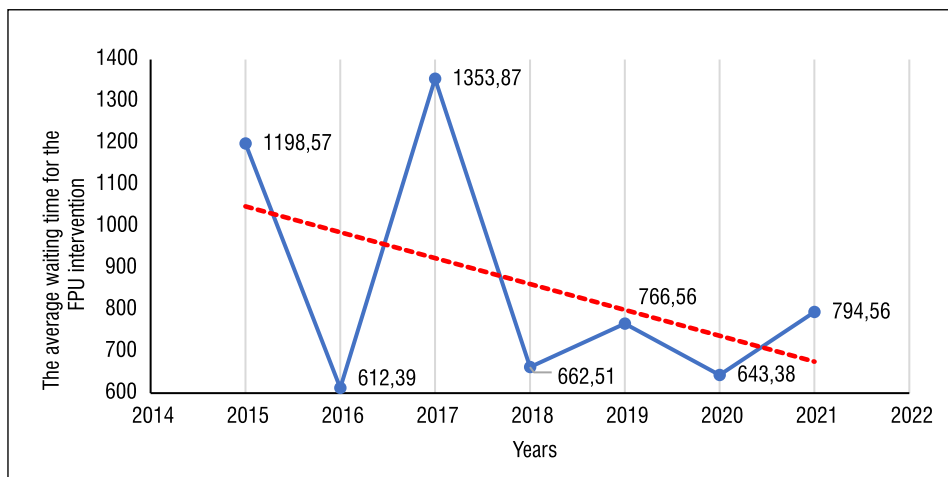


Figure 2. The average waiting time for the FPU intervention from the moment the notification is received to the arrival, in seconds (Source: own elaboration)

moment of receiving the notification, in the analysed period was 910.68 seconds, i.e. 15 minutes and 10 seconds (Fig. 2). For comparison, the average intervention time for fires and local hazards in total in the analysed period was 11 minutes and 26 seconds (fires — 545 seconds, local hazards — 751 seconds).

Of all 1490 interventions included in the analysis, 601 (40,3%) were carried out by professional firefighters. The remaining 889 (59,7%) events were carried out by VFB.

General characteristic

Analysis of selected LHs, when it was necessary to support the operation — in most cases of ventilators for home use among people requiring ventilator-based

therapy (spatial isolation in QGIS) [10–11] shows that most events of such a type occurred in the following voivodeships: Wielkopolskie (285), Śląskie (218) and Mazowieckie (132). The smallest number of events of such a type was recorded in the following voivodeships; Opolskie (14), Zachodniopomorskie (3) and Pomorskie (48), which is illustrated in Figure 3. The colours in the legend and on the map, indicating the respective regions, stand for the intensity scale of events (of the phenomenon under examination).

The average distance of such types of events from the nearest SFS RFU in the period under discussion was 8.39 km ± 6.74 km. The data are shown in Figure 4.

The influence of atmospheric LH (strong winds) on the number of orders to supply power generators

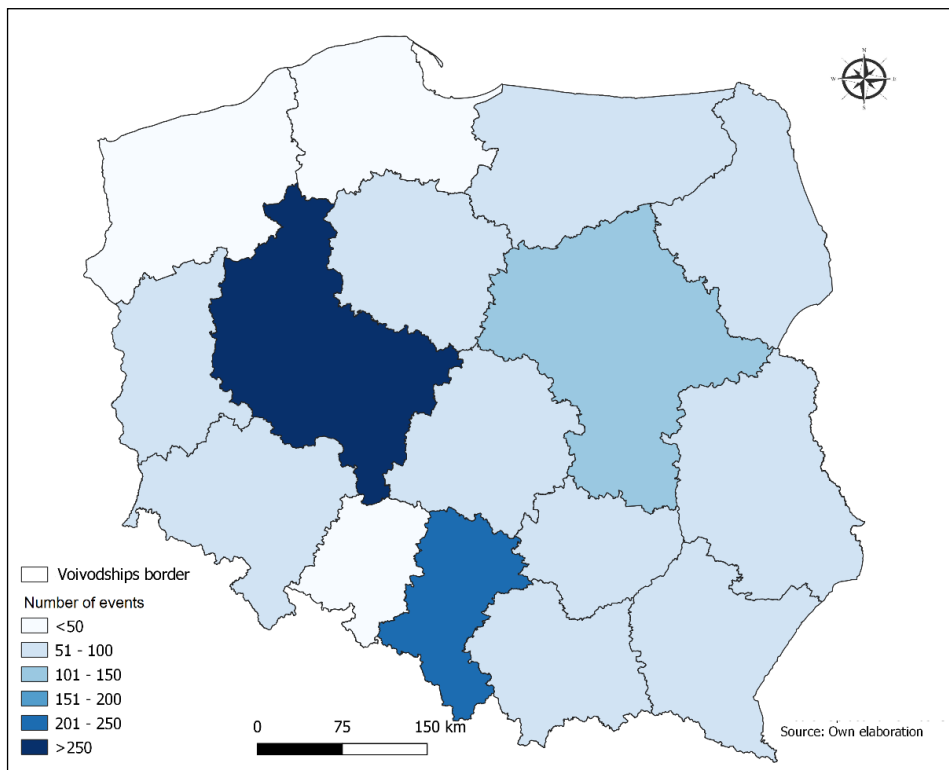


Figure 3. Spatial characteristics of events supporting the proper functioning of home use ventilators (Source: own elaboration based on the collected data)

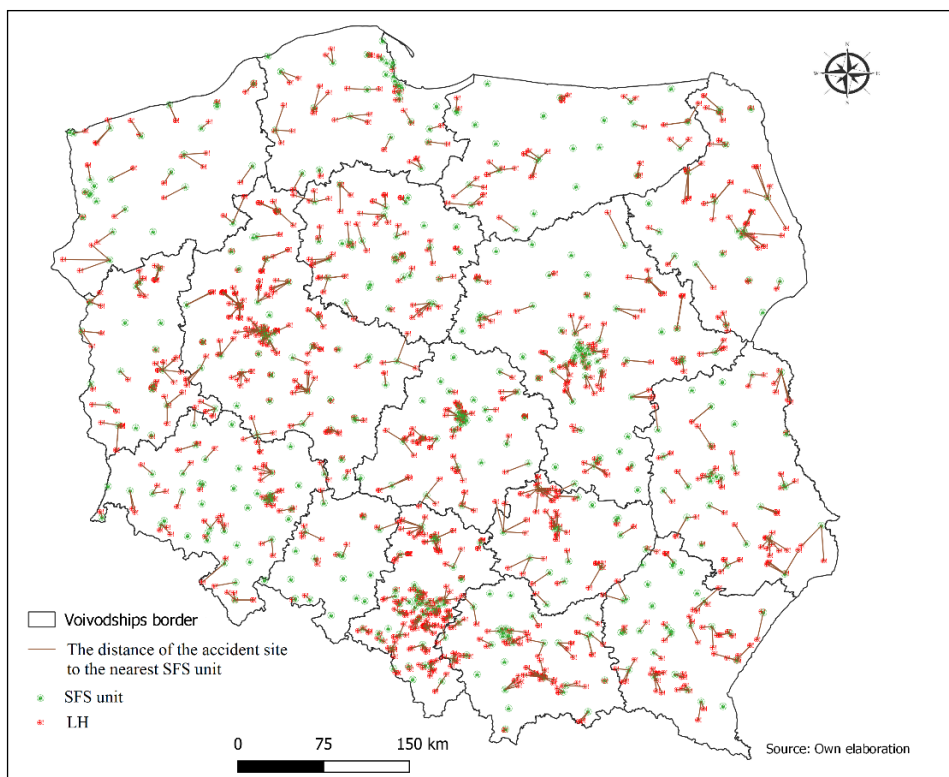


Figure 4. The distance from the accident site to the nearest SFS unit (Source: own elaboration based on the collected data)

Table 1. Characteristics of the variables (high winds vs. home-use medical device)

Variable	N	Mdn	IQR/2	R*	p-value
LH — high winds	468 847	63843.00	9688.50	0.86	< 0.05
LH — home use medical device	1 490	183.00	54.50		

*RSpearman; IQR/2 — semi-interquartile range; Mdn — median

with household devices supporting respiration was demonstrated. Statistical analysis showed a significant correlation ($p < 0.05$, $R = 0.86$) between the number of LH caused by strong winds and the number of LH related to supporting the functioning of home-use medical devices in the analysed period (Tab. 1).

The data presented in Table 2 is only a part of the victims from the entire analysed group: gender, age, and the reason for constant dependence on electrical devices. Among the medical causes of FPU interventions are chronic diseases, complications of injuries, and congenital diseases. In addition, firefighters intervened in care institutions, health care facilities and hospitals during a temporary power outage with no or damaged own emergency power supply. The number of patients is not the same as the number of FPU interventions. In the 7-year analysis, there were 158 interventions for the same patient. For this reason, the analysis covered 1,332 people.

Data in Table 3 concerns 228 people aged 1–97. This is how many people were described in the report prepared by CRA with the characterized age parameter. This group accounts for 17.1% of the entire study population. The mean age of these patients was 51.97 (SD = 26.74) years.

Discussion

The events comprised by the analysis were caused mainly by gales, to a lesser extent by floods (flooding of the transmission facilities and power distribution companies), heavy frosts (excessive voltage leading to line disruptions) and failures in power distribution companies, heavy snowfalls considerably burdening tree boughs.

Causes other than gales were not accessible to the authors in a quantitative way, which results from the report compiled after FPU's intervention. As a result of a fire in a residential building, the emergency services have to evacuate the residents, therefore connecting a substitute power supply for chronically ill people does not occur in fire incidents. After evacuation, sick people are handed over to medical teams in a safe zone.

Today's medical standard enables diverse care of patients with equipment dependent on permanent access to electricity. Patients under the care of Centres

of Home Home Ventilation (CHHV) usually make use of ventilators, but not only. Some patients function at home and use oxygen concentrators, infusion pumps, and air pumps ensuring CPAP during OSA — obstructive sleep apnoea episodes with an appropriately high RDI (respiratory disturbance index) [12–13].

In temporary power failures, the efficiency of the respiratory support devices depends upon emergency supply. Usually, there is no emergency (alternative) supply source in private dwelling places as distinct from medical and long-term care establishments; that is why the efficiency of a device in case of power failure depends upon its battery. The battery efficiency depends, in turn, on the model, and manufacture date (device generation) and ranges from 2–4 hours of continuous operation. The authors did not decide to publish the specifications of random selected models and trade names to avoid making superfluous (unnecessary) suggestions in a research publication.

In the events under analysis, a power failure means fighting against time. The average time of waiting for an FPU's intervention in such events is 15 minutes and 10 seconds. The total waiting time is a sum of a few components: reception of the notification, decision and calling the officers on duty, time of departure, time of arrival, making a reconnaissance of the scene, and time of providing a generating set. Time is crucial for people who cannot breathe on their own and are dependent on a device and electricity [1, 14].

The effect of the SARS-CoV-2 epidemic on the number of calls addressed at the FPUs for preparing generating sets for home use by way of respiratory support was not obvious. In the events under analysis, the number of patients in need of ventilator-based therapy at home due to chronic diseases with complications caused by COVID-19 infection might have increased. On the other hand, people subject to continuous HMV at home might have been recorded as fatalities as more predisposed victims. The authors did not have appropriate data for detailed analysis [15].

An interesting analysis in the section "Results" is a percentage presentation showing what disease entity was the reason for using at-home life-supporting medical devices; there is also a list of certain interventions for the same patient. This signifies difficulties in predicting such hazards, although potentially patients and their families should be prepared for a temporary power failure.

Table 2. General characteristics of the analysed group and the medical causes of the events

Variable		(N = 1490)	100%
Gender	Men	344	23.08
	Women	264	17.71
Age	Adult	185	12.41
	1–18 years	36	2.41
	< One year old	7	0.46
Location	Victim apartment	1476	99.06
	Care facility	9	0.60
	Hospital	5	0.33
Medical equipment	Ventilator	1474	98.92
	Medical suction	3	0.20
	Oxygen concentrator	11	0.73
	Nutritional pump	1	0.06
	Anti-bedsore mattress	1	0.06
Intervention	Re-intervention	158	10.6
Medical cause	Asthma	1	0.06
	Sleep apnoea	1	0.06
	Lung cancer	4	0.26
	Waiting for a lung transplant	1	0.06
	Muscular dystrophy	1	0.06
	Cerebral palsy	3	0.20
	Cystic fibrosis	1	0.06
	Tetraplegia	1	0.06
	Unconscious	2	0.26
	Respiratory failure	9	0.64
	Circulation failure	2	0.13
	Chronic lung disease	4	0.26
	Condition after lung surgery	2	0.13
	Focal brain damage	1	0.06
	Paralysis of the respiratory nerves	1	0.06
	COVID-19 complication	1	0.06
	Sclerosis multiple	1	0.06
	Birth defects	1	0.06
	Respiratory muscle atrophy	1	0.06

Source: Authors' elaboration based on State Fire Service reports

Table 3. The age structure of the victims — a group separated from the reports that described their age

	M	SD	IQR/2	Minimum	Maximum	Skew
Age [years]	51.97	26.74	20.50	1.00	97.00	-0.69

IQR/2 — semi-interquartile range; M – mean, SD – standard deviation

As early as 2012, King [16] described this problem in the USA and noticed a fast growth in patients requiring prolonged mechanical ventilation. Due to better care at ITU many patients who have experienced acute respiratory failure (ARF) need prolonged mechanical ventilation during the period of convalescence (e.g. at home), so the manufacturers of ventilators still endeavour to improve models for house use. In turn, Hind et al. [17] claim that the evolution of mechanical ventilation for home use in the form of non-invasive ventilation with positive pressure led to a widespread rise in home use ventilation worldwide and a smaller number of patients subject to mechanical ventilation.

Ventilators for house use are dedicated to continuous ventilation of patients with controllable and adjustable pressure and ventilation volume in patients with respiratory failure. Ventilation may take place either with the air from the environment or in a mixture of oxygen. The own analysis did not comprise such a division of parameters.

According to the data from the manufacturers, devices are supplied from the mains, internal power sources like a battery or external sources — from a car battery (used in most cases during longer transports of a patient). The efficiency of the internal supply, specified by the manufacturer as the portable mode in case of power failure ranges from 120 to 240 minutes. The time interval must depend upon the battery charge level, average values of ventilation and environmental conditions. Hence, the time of FPU's intervention (Fig. 2), followed by a fast arrival and preparation of a generating set is crucial for the patient and a hazard to his life.

An extension of the power grid and the connection of new recipients have scheduled actions, so the power distribution company which has any patients in its catchment area either notifies them or provides a portable emergency supply in trouble spots. The situation is more difficult in the case of people referred to in the present analysis in which case a power failure is sudden, unscheduled and it is impossible to predict the accurate time of failure.

Interesting can be a comparison of FPU's interventions with generating sets vs. weather data regarding violent weather changes accompanied by gales. From 4th to 6th October 2017, Poland was scourged by hurricane Ksawery [18–19]. Eighty-four (5.65%) of events under analysis fall in that period due to the destructive power of gales.

In the situations described, a person who calls services often reported that a ventilator was still in operation, went into the battery supply mode, and the remaining working time is 1, 2, or 4 hours.

Because of the lack of information on when the electric power supply will be restored, firemen were asked for help bearing in mind the health condition of

a patient. The problem of lacking detailed data, availability and rendering services for people subject to HMV, crucial data for planning the health care system and ensuring appropriate resources are described by other researchers in other parts of the world [20–21].

Limitations

In many cases, it was impossible to collect patients' medical data, viz. diseases and traumas, which entail the use of ventilators and other electrical medical devices. A report compiled by the person in charge of a rescue action (CRA) of the SFS (which is not the leading service in medical interventions) did not specify the medical details of an incident [22]. Information pertinent to the age of the victims with a breakdown into the sexes is incomplete, however, it can offer interesting observations, e.g., 43 interventions regarded minors, which can show the scale of the problem concerning the permanent medical care of patients suffering at such a young age and is described by other authors [23]. Detailed attainable results are summarized in Table 2.

Conclusions

The number of interventions covered by the analysis correlates only with local hazards. A significant element of rescue actions are VFBs squads for being better deployed in rural areas, provided with generating sets; they can ensure an emergency electricity source faster. Local government authorities should have in their emergency management divisions a list of crucial addresses, subject to continuous updating. Power failures need not always mean a threat to one's life; in many cases, a patient may be functional for many hours, when bereft of specialistic devices without which his or her life quality and comfort will be considerably lower. Persons in charge of a rescue action should draw up the medical part of a report more accurately (concerning the victim and the disease entity) while performing advanced first aid (AFA) procedures.

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