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APPROACH TO ASSESSING THE PREPAREDNESS OF HOSPITALS TO POWER OUTAGES

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Research article

Abstract: Within the secondary impacts of electricity blackouts, it is necessary to pay attention to facilities providing medical care for the population, namely the hospitals. Hospitals represent a key position in the provision of health care also in times of crisis. These facilities must provide constant care; it is therefore essential that the preparedness of such facilities is kept at a high level. The basic aim of this article is to analyse the preparedness of hospitals to power outages (power failures, blackouts) within a pilot study. On that basis, a SWOT analysis is used to determine strengths and weaknesses of the system of preparedness of hospitals to power outages and solutions for better security of hospitals are defined. The sample investigated consists of four hospitals founded by the Regional Authority (hospitals Nos. 1-4) and one hospital founded by the Ministry of Health of the Czech Republic (hospital No. 5). The results of the study shows that most weaknesses of the preparedness of hospitals are represented by inadequately addressed reserves of fuel for the main backup power supply, poor knowledge of employees who are insufficiently retrained, and old backup power supplies (even 35 years in some cases).

Keywords: Preparedness, hospitals, power outages, assessment, SWOT.

Introduction

Consequences of emergencies and crisis situations lead to direct and indirect threats to lives, health and the environment in which we occur. It is badly needed to identify the impacts of various emergencies and crisis situations and propose steps to mitigate their impacts. One significant part of crisis management is to search for and mitigate the risks threatening the population dependent on assistance and care in health facilities. These facilities perform regular and constant care of clients who have reduced self-sufficiency due to health reasons, and it is necessary to provide them with such services even during the emergency or crisis situation.

The basic function of the state in emergencies and crisis situations in the health sector is to ensure urgent health care and public health protection. Exactly these services are based on the functionality of the entire system of facilities within health infrastructure of the state. In addressing emergencies and crisis situations, the health care system must always be understood as a whole. Legal regulations (Act 239, 2000; Act 240, 2004; Decree 380, 2000) and the methodology of the Ministry of Interior regarding the preparation of crisis preparedness plans for health care facilities such as hospitals (Methodology of preparing crisis preparedness plans) show that health care facilities are processors of crisis preparedness plans, whereas these plans describe the organization of relevant activities and provision of relevant resources (material and personnel) necessary to secure the task of legal persons for the duration of the crisis situation.

Healthcare facilities have an irreplaceable role in the health system because medical personnel cannot be replaced by lay volunteers; therefore, preventive measures in this direction focus on the best possible protection and security of specialist staff. In case of emergency and crisis situations, very important aspect of medical facilities is the ability to maintain the capacity and capabilities of

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such facilities. In the event of emergencies and crisis situations with a duration of tens of days or longer, the preparedness and effectiveness of the system of emergency management has a limit significance for the functionality of the entire health system.

Healthcare facilities providing health care must be adequately staffed, materially and technically equipped for the type and scope of health care which they provide. Particular specification of requirements for material and technical equipment of health facilities are given in the Decree on requirements for the minimum technical and material equipment of health facilities and home care contact centres (Decree 92, 2012). These requirements state that medical facilities must enable functional and safe operation in terms of engineering requirements for spaces and their functional and layout arrangement. To ensure that health facilities can provide medical care under any circumstances, it is necessary to define and configure the system of their preparedness.

Some cases of electrical power failures show us how important it is to address not only technical aspects but also the impact on the population. In the US, after a blackout in 2003, they started to analyse medical facilities and explore their readiness and ability to provide medical care even during electrical power outages. The research took place in health facilities in Ohio, Michigan and New York. It turned out that the biggest problem during the power outage consisted in malfunctions of communication channels, problems with diesel generators which ceased to supply power, failures of manpower and other psychological factors. Power outages had a major impact on the functionality of healthcare infrastructure and healthcare delivery. Good news was that mortality or morbidity did not rise (Kile et al., 2005).

In early 2012, a big problem was the blackout in Slovenia (Czech Television, 2012). One hundred and fifty thousand households were without electricity supply for several days. The situation was so complicated because the outage happened during heavy snowfall and Slovenia was literally covered with ice. People remained without heat, water and food supplies. To resolve the situation, the Slovenian government called in the army and asked for help by the European Union and neighbouring countries, including the Czech Republic (Marek and Vojtěch, 2014).

Another example is the storm that hit California on February 9, 2014. The worst affected place was the district of Sonoma where the storm caused a series of electricity outages and about 5000 people remained without supplies of food and water (Hansen and McCallum, 2014).

Regarding larger outages, it is possible to mention Hurricane Sandy in 2012, formed in the Caribbean area on October 22, 2012, which struck the east coast of the United States, where it caused damage in the order of tens of billions of dollars (Koplowitz, 2012). On the east coast of the United States, about 6 million people in seven states remained without electric energy supplies for several days. During the storm, it was necessary to evacuate the Tish University Hospital in New York, where diesel generators totally failed. Patients were transported by ambulances to nearby hospitals (McCoy and Weise, 2012; Redlener, 2012).

Materials and methods

In the context of assessing the preparedness of hospitals to power outages, it was first necessary to assess the healthcare planning in terms of legal standards and standards of non-legislative nature. It was necessary to focus on the individual laws and concepts that are mandatory for solving the preparedness of hospitals, and determine the most important standards that help to consolidate this system. Based on this analysis, it was possible to compile a key questionnaire and collect data in individual hospitals using the PAPI method (Hendl, 2005), and sort and assess these data afterwards. The assessment was based on using the SWOT method which enabled to simply and efficiently determine the strengths and weaknesses of the overall preparedness system and identify key elements that would lead to the improvement of the system.

Planning in healthcare

Planning in healthcare, related to its security, should be based on determining the critical aspects of healthcare or critical aspects for the population in case of failure of or damage to the healthcare system. It is mainly due to the fact that contemporary threats aim at vital and state-protected interests. For planning in the healthcare sector, in addition to the Conception of crisis preparedness in healthcare (Conception, 2007), there are also type plans and plans for emergency preparedness (Fišer, 2006). Currently, 22 types of threats with unacceptable risk are defined. For all these types of threats, it is necessary to develop new type plans by the end of 2017. One of the type plans is the type plan “Epidemics - mass infection of persons”, which falls within the competency of the Ministry of Health.

Other plans are plans for crissis preparedness, serving for designated entities to protect their own operations in crisis situations. This plan can also serve as a basis for drawing a traumatological plan of healthcare providers. Within the framework of the activities of specialized departments of health regions, the basis for crisis management is also the coordination and supervision over fulfilling the tasks from the regional crisis plan in the concerned medical facilities, i.e. hospitals in our case, namely the preparation of the plan of crissis preparedness. This plan is processed by medical facilities and medical institutes to ensure the performance of activities and their competencies in case of crisis situations. Crisis preparedness of the health facilities must eliminate any unpredictable situation to which such facilities are not able to respond (Fišer, 2006).

As mentioned above, the primary function of the state in crisis and emergency situations is to ensure emergency health care and protection of public health. During their operation, large hospitals fumble with occasional dysfunctions, such as lack of clean laundry for beds in intensive care (intensive care units) and resuscitation (anaesthetic-resuscitation wards), pneumatic post overloads or stoppages at peak times, malfunction of devices before the weekend with service not available until Monday, shortage of beds in intensive care, etc. For these reasons, sudden and unexpected outages - affecting the whole hospital or its part and interfering with its operation and activities - are very demanding. Preparedness for these situations is therefore very necessary.

Electricity outages are considered one of the most serious threats to economic development. Global Risks (2014) report pointed to a high probability of blackouts with extensive economic impacts (Pourbeiket al., 2006). Blackout may afflict any country worldwide. One of the large-scale blackouts occurred in north-eastern and central parts of the United States and hit several hospitals at the same time. Electricity outage occurred in 2003 and affected a total of four hospitals. Electricity began to be gradually connected after 12 hours and supplies were fully restored after 72 hours. The biggest complications included connection problems within hospitals, with other hospitals, within the city and district, and with the state emergency management centre; updated lists for calling doctors and staff were not at disposal, hospital pagers did not function, reception by mobile phones was sporadic, internet and intranet networks were unavailable and communication system of rescue services did not work. Another problem was the fact that the rescue service recorded a number of unnecessary calls despite announcements in the media not to call a hotline except urgent situations. For hospitals and their patients, this outage meant dysfunctional labs, most of the elevators did not work, some emergency wards lost most of electricity, it was not possible to pump oil, morgues had no other source of electricity, refrigerators with drugs were not connected to emergency circuits, pressure in water pipes was low, flush toilets did not function, it was not possible to carry out laboratory tests, etc.

Czech national standards in healthcare

ČSN 33 2140 “Electrical wiring in rooms for medical purposes” (Technical Standard, 1987) applies to the design, operation and maintenance of electrical wiring in rooms for medical purposes, which are located in healthcare facilities. According to this standard, demands on electrical equipment and methods of their ensuring are normalized in 13 requirements. The most important requirements with regard to emergency preparedness include requirement GE = Main emergency source of electrical power, and requirements E1 and E2 = Special emergency sources of electricity. In addition, the standard provides a tabular list of requirements for different rooms and time periods of operational tests according to the above requirements. The standard has a total of 11 annexes which mainly contain examples of some special solutions.

New ČSN 33 2000-7-710 (Technical Standard, 2013) came into force in 2013. For designers, installers, inspection techniques and operational techniques in medical facilities, this brings a challenging period during which they must learn to reliably apply the new standard and also maintain the existing electrical wiring in perfect condition according to the old standard ČSN 33 2140 until its reconstruction. The existence of this standard gives guidance to healthcare facilities regarding the emergency power sources which must be acquired and wards which must be kept operational.

Data collection

For the purpose of examining and assessing the preparedness of hospitals to power outages, we used a pilot study covering selected hospitals established by Regions and the Ministry of Health.

For the purposes of data collection, as research objects, we selected health care facilities providing inpatient care (standard acute inpatient care, intensive acute inpatient care, subsequent inpatient care, long-term inpatient care) pursuant to the act on health services and terms of their provision, where founders are regions and the Ministry of Health (Act 372, 2011).

Data collection was using the PAPI method which offers many positives, mostly in the approach to interviewees (respondents). One of the positives is the direct contact with the interviewee. In each hospital, the given problem was explained and each question was additionally clarified in case of misunderstanding. The answers of the respondents were austere and distant; conversely, they were supplemented with additional information concerning the specifics of each hospital. This makes the data relevant. Subsequently, the collected data were assessed using the SWOT analysis.

Results

Individual information regarding the preparedness to power outages is collectively written for each hospital. In each hospital, it was necessary to acquire general information regarding the supply of electricity: distributor, number of electricity service lines, and the eventual use of other alternative sources of electricity.

Subsequently, it was necessary to find out specific information with regard to operational restrictions in the event of an outage. It was necessary to identify wards which will not function in such a case, wards which will still provide care and the extent of this care (whether the care will be restricted or not).

The last point of the analysis was to identify emergency power sources. The analysis focused on the issue of emergency sources that the hospital has - wards which have their own emergency source and wards connected to the main emergency source. It was necessary to analyse the amount of fuel available to various hospitals and ascertain the time during which the hospitals are self-sufficient (according to the average consumption of diesel generators, which is very highly variable depending on instantaneous take-offs). The results obtained are described in relation to individual hospitals.

Hospital 1

Hospital 1 has four electricity service lines (two aerial lines and two cable lines). Distributor of this electricity is the company E.ON a.s., which is able to switch between these lines if necessary, whereas the supplies are brought from different substations. Directly in the premises of hospital 1, there is a gas cogeneration unit which produces electricity by burning gas; due to this fact, hospital 1 heats the water and sells the electricity produced to the company E.ON a.s. Emergency power supply is secured through an UPS, diesel generator and batteries.

In the event of a power failure, the hospital would be forced to curtail its operations. This would mainly relate to restrictions on different kinds of radiodiagnostic examinations (CT, SONO, X-ray and skiascopy). Some hospital wards (ophthalmology, ORL, TRN, dermatovenorology, and others) would reduce their operation significantly. Other parts of the hospital (such as a kitchen or laundry room) would not work.

During power outages, in terms of providing the hospital acute and inpatient care, it is necessary to ensure operation of critical wards (anaesthetic-resuscitation ward, intensive care unit, surgery - operating theatres, and biochemistry ward). This can be achieved by ensuring adequate reserve (alternative) sources of electric power, which are defined by the new technical standard “Electrical wiring in rooms for medical purposes” (Technical Standard, 2013) and the still valid standard “Electrical wiring in rooms for medical purposes” (Technical Standard, 1987). These standards define types of reserve sources which should be available in medical facilities.

The most important backup power source in hospital 1 is a diesel generator which is regularly tested once a week with load and once a week without load. Another reserve backup source is an UPS unit and the so-called battery room (room with rechargeable batteries - the old type of backup power source; at present, the system is gradually converted to new types of backup sources such as UPS). Types of alternative backup power sources in hospital 1 are presented in Tab. 1.

An important area of preparedness of hospitals to power outages is the amount of fuel available as fuel for diesel generators. In hospital 1, there are 200 litres of diesel fuel directly nearby the diesel generator and other 200 litres of diesel oil in barrels. At the given average diesel generator consumption of 100 litres/hour, the operation of hospital 1 will be secured for 4 hours. After this period of time, hospital 1 will have to ensure delivery of oil, which is not covered by contract. According to the analysis of information, hospital 1 would ensure the oil purchase from the nearest filling station. The question is whether the filling station would be in operation during the power outage.

Tab. 1 Types of alternative backup power sources

Alternative power source	Number	Output	Fuel consumption
UPS	1	3.5 kW	-
Diesel generator	1	400 kW	100 - 120 litres/hour
Rechargeable batteries	2	16.8 kW	-

Hospital 2

Hospital 2 has two electricity service lines. Distributor of this electricity is the company E.ON a.s., which is able to switch between these lines if necessary, whereas the supplies are brought from two different substations. In hospital 2, the emergency power supply is secured by 4 UPS units and 2 diesel generators.

In the event of a power failure, the hospital would be forced to curtail its operations. This would mainly relate to restrictions on various kinds of radiodiagnostic examinations, specialized wards and operational-technical equipment.

During power outages, in terms of providing the hospital acute and inpatient care, it is necessary to ensure operation of critical wards (anaesthetic-resuscitation ward, intensive care unit, surgery - operating theatres, and biochemistry ward). This can be partly achieved by ensuring adequate alternative sources of electricity according to Technical Standards (2013 and 1987).

In hospital 2, the most important backup power sources are diesel generators which are regularly tested once a week with load and once a week without load. Other backup alternative sources are 4 UPS units which ensure the operation of the operating theatre, anaesthetic-resuscitation ward, neonatology and biochemistry ward. Types of alternative backup power sources in hospital 2 are presented in Tab. 2.

An important area of preparedness of hospitals to power outages is the amount of fuel available as fuel for diesel generators. In hospital 2, there are 2 x 120 litres of diesel fuel directly nearby the diesel generator and other 2 barrels with the volume of 200 litres. At the given average diesel generator consumption of 50 litres/hour, the operation of hospital 2 will be secured for 12 hours. One diesel generator will always be in operation. The other one is merely a backup.

After this period of time, hospital 2 will have to ensure delivery of oil, which is not covered by contract. Hospital 2 would ensure the oil purchase from the nearest filling station.

Tab. 2 Types of alternative backup power sources

Alternative power source	Number	Output	Age	Fuel consumption
UPS	4	-	-	-
Diesel generator	2	230 and 90 kW	30 and 32 years	50 litres/hour

Hospital 3

Hospital 3 has two electricity service lines. Distributor of this electricity is the company E.ON a.s. In hospital 3, the emergency power supply is secured by 3 UPS units, one diesel generator and 3 mobile power generators.

In the event of a power failure, the hospital would be forced to curtail its operation in ordinary wards. In this hospital, only emergency elevators and emergency lighting would remain functional. The hospital would have to limit a number of specialized examinations (such as CT or X-ray) and operational-technical departments.

During power outages, in terms of providing the hospital acute and inpatient care, it is necessary to ensure operation of important wards specific to this hospital (intensive care unit, surgery - operating theatres, gynecological and maternity ward). This can be partly achieved by ensuring adequate alternative sources of electricity according to Technical Standards (2013 and 1987).

In hospital 3, the most important backup power source is a diesel generator which is regularly tested once a week with load and once a week without load. Other reserve backup sources are 3 UPS units which ensure the operation of the operating theatre, intensive care unit, gynecological and maternity ward. Types of alternative backup power sources in hospital 3 are presented in Tab. 3.

An important area of preparedness of hospitals to power outages is the amount of fuel available as fuel for diesel generators. In hospital 3, there are 400 litres of diesel fuel directly nearby the diesel generator and other barrels with the volume of 400 litres. At the given average diesel generator consumption of 60 litres/hour, the operation of hospital 3 will be secured for 13 hours. After this period of time, hospital 3 will have to ensure delivery of oil, which is not covered by contract. Hospital 3 would ensure the oil purchase from the nearest filling station.

In hospital 3, a significant increase in preparedness to power outages was achieved through mobile power generators. The hospital has extensive experience in power outages, either in the form of cut-offs announced in advance by the company E.ON, a.s. or undesired incidents. With these events, the hospital faced problems that accompany power failure. From a technical point of view, emergency electricity was duly supplied but some wards remained without power. This was caused by a technical defect in the cable line that had to be addressed immediately. The quickest way was to buy a mobile power generator which proved good and become another alternative source of electricity in the event of technical failure.

Tab. 3 Types of alternative backup power sources

Alternative power source	Number	Output	Fuel consumption
UPS	3	-	-
Diesel generator	1	272 kW	60 litres/hour
Mobile power generator	3	6 kW	-

Hospital 4

Hospital 4 has two electricity service lines. Distributor of this electricity is the company E.ON a.s. Directly in the premises of hospital 4, there are 2 gas cogeneration units which produce 2 x 140 kW of electricity. This electricity is intended only for the needs of the hospital; the units are shut down in the event of a power failure. In this hospital, the emergency power supply is secured by an UPS unit, diesel generator and rechargeable batteries.

During power outages, in terms of providing the hospital acute and inpatient care, it is necessary to ensure operation of wards specific to this hospital. This can be partly achieved by ensuring adequate alternative sources of electricity according to Technical Standards (2013 and 1987).

In hospital 4, the most important backup power source is a diesel generator which is regularly tested once a week with load and once a week without load. Other backup alternative sources are represented by 7 UPS units which ensure the operation of the labour ward, 3 operating theatres, central sterilization, intensive care unit and clinical biochemistry department. Types of alternative backup power sources in hospital 4 are presented in Tab. 4.

An important area of preparedness of hospitals to power outages is the amount of fuel available as fuel for diesel generators. In hospital 4, there are 400 litres of diesel fuel directly nearby the diesel generator and other barrels with the volume of 400 litres. At the given average diesel generator consumption of 40 litres/hour, the operation of hospital 4 will be secured for 20 hours.

After this period of time, hospital 4 will have to ensure delivery of oil, which is not covered by contract. Hospital 4 would ensure the oil purchase from the nearest filling station.

Tab. 4 Types of alternative backup power sources

Alternative power source	Number	Output	Age	Fuel consumption
UPS	7	-	-	-
Diesel generator	2	160 kW	35 years	40 litres/hour
Battery room	1	-	-	-

Hospital 5

Electricity network around hospital 5 is a 110 kV high-voltage distribution network; new 110 kV power nodes were connected to increase its transmission capacity and operational security. This can be partly achieved by ensuring adequate alternative sources of electricity according to Technical Standards (2013 and 1987). Within its premises, hospital 5 has alternative sources in case of power failure. These premises are called energy blocks. In the hospital, there are several blocks of this type, which are part of individual hospital buildings or separate objects.

Inside energy blocks, there are diesel generators, machines supplying electricity to important workplaces and operations from a public source in case of power outages for the necessary period of time. Energy blocks also contain tanks with backup diesel fuel. The necessary period of time is set to a minimum of 15 hours. Failure of one energy block would not result in failures of other blocks. A schedule is prepared for each energy block and the relevant workplace of hospital 5 to verify the functionality of energy blocks, their functions and diesel fuel sufficiency (for odd and even weeks, detailing the time and tests with load and without load).

Tab. 5 Types of alternative backup power sources

Alternative power source	Number	Output	Age	Fuel consumption
UPS	-	-	-	-
Diesel generator	3	100 - 550 kW	-	260 litres/ hour
Mobile power generator	-	-	-	-

In the rooms for medical purposes, there are electrical circuits that are divided into 4 groups in accordance with their importance. Plug outlets are differentiated by colour according to these groups. The first type includes very important circuits. Special emergency sources (UPS units) provide power even after the failure of the basic or main emergency source within 15 seconds. Sockets have orange colour. The second type includes important circuits. These circuits are connected to alternative sources of electrical energy which power these circuits within 120 seconds after the failure of the central power supply. Sockets have green colour. The third type includes circuits of medical isolated system. The system is powered from important circuits using a protective isolation transformer. Sockets have yellow colour. The fourth type includes less important circuits. Circuits for general use are not connected to backup power sources. Socket colours are arbitrary, except orange yellow, green and red.

Discussion

Within the pilot study, it was necessary to analyse the current state of preparedness of hospitals to power outages. It was necessary to determine the strengths and weaknesses that will facilitate further deeper investigation and determination of solutions which would help hospitals to set up emergency preparedness and ensure their operation even in the event of a power failure.

Strengths in the preparedness of hospitals to power outages

Determined strengths provide a solid foundation to the whole mechanism of preparedness, on which the hospitals can rely in case of ensuring their preparedness. The pilot study shows that it is a good basis for the entire system, which must be developed and built up. Strengths are presented in Tab. 6:

1. *Relevant standards:* Existence of Technical Standards (2013 and 1987) provides guidance for the fundamental resolution to the crisis preparedness of hospitals with regard to technical solutions.
2. *Qualified personnel:* In each hospital, there is at least one employee responsible for the emergency power supply. This employee has the required qualifications and enough experience, knows the technical condition of medical equipment and is responsible for the functionality of individual components of the emergency power supply system in the hospital.
3. *Central diesel generator:* In each hospital, there is at least one central diesel generator which retains the functionality of specified parts of the hospital within 120 seconds after the power supply from the grid has failed. Diesel generators allow partial and basic operation of the hospital and provision of basic medical care as needed.
4. *Regular testing of emergency sources:* Tests must be conducted regularly whereas their frequency is determined by ČSN. These tests ensure their functionality and readiness for power outages.
5. *Own mobile power generators:* Some hospitals have mobile power generators which can be used in places separated from emergency power supplies, or when the electricity transmission fails and it is necessary to restore supplies in important locations.

Weaknesses in the preparedness of hospitals to power outages

Determined weaknesses pose the greatest problem in ensuring emergency preparedness. All items described below represent weaknesses which indicate poor security of hospitals with regard to power outages. The results of the pilot study highlighted the future need to change the whole system and rethink the mechanisms and approaches which are currently set in the context of emergency preparedness of hospitals. Weaknesses are presented in Tab. 6:

1. *Technical security:* At present, the medical facilities are not capable of ensuring specialized examinations (such as CT, SONO, X-ray and skiascopy) in the event of electrical power failures. Energy demands of the respective devices do not allow them to be connected to emergency power sources.
2. *Fuels:* In the hospitals, there are reserves of fuel to ensure the operation of emergency power sources for about 10-12 hours. The average consumption of diesel generators is high and reaches 70-80 litres/hour. When the reserves are consumed and smooth supply of fuel is interrupted, the diesel generator stops running; afterwards, this adversely affects the operation of the hospital, especially in the sphere of health care for clients.
3. *Technically outdated backup sources:* Some hospitals are still equipped with technically outdated battery charging stations to ensure transmission of electrical energy from the battery charging station to electrical distribution systems. Compared to modern UPS units, this type of sources is quite difficult to maintain, especially with regard to the frequency of repairs needed.
4. *Knowledge of personnel:* Insufficient awareness of the issue of large-scale electrical power failures by both the operating personnel and management participates in the increased probability of equipment failure and lay-up, at least on a limited scale.
5. *Documentation:* Documentation available in hospitals is at good level but no documentation resolves preferential fuel supply for emergency power sources during a power failure.

Opportunities in the preparedness of hospitals to power outages

Currently, we have identified four areas that could serve to improve the system of emergency preparedness. These mainly include technical and operational parts that require sufficient funding

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and knowledgeable staff dealing with this issue. Opportunities are presented in Tab. 6:

1. *Updating of the plans:* Some medical facilities are obliged to draw up plans for emergency preparedness fulfilling tasks from the regional crisis preparedness plan, in which the hospital management should implement, among other things, preferential fuel supply for emergency power sources in the facility and add entities lending mobile power generators.
2. *Modernization of diesel generators:* Most diesel generators, which the hospitals can use, were acquired in the 1980s-1990s. Parameters of these diesel generators are lagging behind parameters of current sources; at the same time, frequency of their repairs increases and this ultimately affects the operation of the hospital. Therefore, it is advisable to modernize equipment through new and more powerful diesel generators.
3. *Modernization of backup sources of E1 and E2 types:* At the present time, the hospitals are gradually switching to modern UPS units; however, outdated battery charging stations are still used in some of them.
4. *Mobile power generators:* Through acquisitions of mobile power generator, the hospitals can resolve some power outages in places separated from electricity supplies from diesel generators or secure operation of individual wards in case of failure.

Threats in the preparedness of hospitals to power outages

The biggest problem of the functioning of hospitals during electrical power failures is represented by factors that can enter the system from outside. This mainly relates to the lack of financial resources and possible underestimation of this issue at the level of state and local governments. Threats are presented in Tab. 6:

1. *Limited financial resources:* Financial resources are one of the biggest problems which various health facilities are currently facing. Their lack does not allow modernization of equipment for securing emergency power supplies; typically, the funds for refurbishment and renovation of technical equipment are not available.
2. *Failures of backup sources:* This threat poses a serious threat to the operation of the facilities. A failure of emergency power source in the hospital occurred in 1998, during a power outage in New Zealand.
3. *Fuels:* Large fuel consumption may lead to power supply failure and possible accumulation of other emergencies.
4. *Domino effects on critical infrastructure:* Electricity outage brings domino effects on critical infrastructure; this can cause paralysis of other important commodities which are needed for medical facilities (e.g. water supply, etc).

Evaluation of the SWOT analysis

To accept proper strategies for improving emergency preparedness of hospitals, it was necessary to assess the SWOT analysis qualitatively. The assessment was based on the multi-criteria evaluation using Fuller's method, where each criterion is given its weight and subsequently, on grounds of expert estimate, its evaluation (the so-called score). For strengths and opportunities, we used a positive scale from 1 to 5, where the value of 5 indicates the highest satisfaction. For weaknesses and threats, we used a negative scale from -1 to -5, where the values of -1 and -5 indicate the lowest and highest dissatisfaction, respectively. The final comparison of internal and external indicators resulted in the value of -0.79, which indicates a very weak solution of these problems in hospitals.

Tab. 6 SWOT analysis of the preparedness of hospitals to power outages

	STRENGTHS		
		weight	evaluation
1	Relevant standards	0,2	3
2	Qualified personnel	0,27	3
3	Central diesel generator	0,33	4
4	Regular testing of emergency sources	0,13	5
5	Own mobile power generators	0,07	3
	TOTAL	**3,59**	
	OPPORTUNITIES		
		weight	evaluation
1	Updating of the plans	0,2	5
2	Modernization of diesel generators	0,4	4
3	Modernization of backup sources of E1 and E2 types	0,3	3
4	Mobile power generators	0,1	2
	TOTAL	**3,7**	
	WEAKNESSES		
		weight	evaluation
1	Technical security	0,14	-3
2	Fuels	0,29	-5
3	Technically outdated backup sources	0,21	-4
4	Knowledge of personnel	0,29	-3
5	Documentation	0,07	-3
	TOTAL	**-3,58**	
	THREATS		
		weight	evaluation
1	Limited financial resources	0,3	-5
2	Failures of backup sources	0,1	-2
3	Fuels	0,2	-4
4	Domino effects on critical infrastructure	0,4	-5
	TOTAL	**-4,5**	

Balance of the SWOT analysis

The investigation shows that all the hospitals have a diesel generator. Specific technical requirements for ensuring emergency electricity supplies are defined in Technical Standards (2013 and 1987). Each hospital has at least one main emergency source of electricity - diesel generator. All the generators available in various hospitals were acquired before 30 - 35 years. Consultations with experts indicate that the advantage of older generators consists in their relatively simple and inexpensive repair in case of faults, and that their main drawback is low reliability, despite the numerous tests made at regular weekly intervals.

The aim of the tests, which take place alternately with load and without load on a weekly basis, is to verify the functionality of diesel generators. The test without load is used to check the start-up speed of the generator which must be able to supply power within 120 seconds. In all the hospitals, it was found that this period does not exceed 20 seconds. The test with load is used to check parameters of diesel generators and connection to the hospital network. Although these tests are carried out according to Technical Standards (2013 and 1987), they can cause considerable complications for the hospital. Disconnection of the hospital from the grid and reconnection to the emergency power source affects activities of many medical devices and may lead to impairment of laboratory tests. It is also vital to always coordinate these tests with surgery activities in order to avoid any effects on medical equipment due to the changeover between the grid and generator. The tests are therefore conducted mostly in the early morning and all the wards (departments) are warned of these tests in advance.

All diesel generators are subject to mandatory inspection tests during which service fluids are changed and the overall condition of generators is checked. These revisions are carried out by an independent firm, but they are quite expensive.

Emergency power supplies by diesel generators require sufficient reserves of fuel - diesel oil. It was found that fuel reserves in hospitals are roughly for 6-12 hours of operation; however, the consumption is high and ranges from 30 to 100 litres/hour, depending on the energy need of the respective hospital, season and other factors. The quality of diesel oil is determined by the decree on the quality and evidence of fuel (Decree 133, 2010). For propulsion of diesel generators (such as backup sources of hospitals, rescue and fire brigades), this decree recommends only fossil motor oil, i.e. motor oil without any addition of biofuels, preferably arctic motor oil. This quality grade of diesel fuel is not distributed in the Czech Republic.

Hospitals have not yet solved preferential supplies with fuel and all buy fuel at petrol stations. During massive power failures, however, the majority of petrol pumps will not be in operation.

As a special emergency power source, all hospitals use UPS units or old battery charging stations. These devices should bridge the period between the loss of power from the grid and supplies from diesel generators. These emergency sources should be designed to supply electricity for three hours. However, the supplies depend on the instantaneous take-off by the respective ward and the time horizon regarding the endurance of these devices cannot be precisely defined.

During power outages, operation of hospitals will be partially restricted, but this will not result in any serious danger to the health and lives of clients. The biggest limitation of hospitals is seen in radiodiagnostic imaging devices such as CT, X-ray, MRI and others, where the energy requirements for running these devices are high and the main emergency power source would not handle such a load. In this situation, it is possible to use a portable X-ray unit which is located in the operating theatres and whose energy requirements are lower than in stationary X-ray devices. In all hospitals, except the restriction of radiodiagnostic departments, the operation of laundry, dining room and kitchen would also be limited; this represent a major problem with securing food for patients and staff.

To enhance the preparedness of hospitals to power outages, it will be necessary to gradually modern the entire system of emergency power supply. Initial step is to enhance the performance of generators and replace wiring materials and electrical wiring. Electrical wiring in older hospitals is outdated; it was designed for take-offs 30 years ago while today's requirements for wiring are substantially higher. At present, the hospitals modernize individual backup power sources, i.e. they are switching from battery charging rooms to modern UP units which have more sophisticated approach to providing instant energy for strategic wards and departments.

Conclusion

In the Czech Republic, no long-term and extensive power failure (blackout) occurred so far. The electricity grid is relatively strong and stable; this gives a certain amount of trust in the power distributors in terms of providing regular supplies. In this simplified view, power outages are hardly likely.

However, impacts of power failure are considerable. It is therefore necessary to continue to strengthen at least the basic preparedness in facilities which depend on electricity and which are not able to provide medical care at the desired level without it. A special position in the healthcare system appertains to hospitals; in these healthcare facilities, power outages immediately threaten lives of their clients. For this reason, each medical facility must have its own alternative source of electricity.

In hospitals, all issues of power outages are solved and conceived with regard to failures lasting for several hours. There is no preparedness for large and widespread outages affecting the entire region and related commodities such as water, heat, gas, food, etc.

The research included five selected hospitals which have undergone the analysis of preparedness to power outages. SWOT analysis has been chosen due to a quick insight into the issue and rapid evaluation of the state of preparedness with respect to internal and external factors that enter the preparedness system. The results show that the balance of this SWOT analysis is not very flattering. The resulting value (-0.79) means that it is necessary to work on improving the preparedness mechanism. It is especially necessary to update emergency preparedness plans, involve founders of hospitals to a greater extent and focus on technical condition of emergency sources.

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