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Research Article

Investigating Safety Standards and Performance of Emergency Power Diesel Generators in Hospitals of Tabriz, Iran

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Abstract

Background: Power outage risk is one of the serious risks that could be eliminated by supplying electricity through the emergency power system installed in a hospital, such as diesel generators and uninterruptible power supplies (UPSs).

Objectives: The present study aimed to investigate the observance of safety and maintenance standards of emergency power diesel generators in the hospitals of Tabriz.

Methods: This descriptive-analytical research was cross-sectionally performed in 18 hospitals of Tabriz in 2014. The data collection tools included a questionnaire and a checklist prepared according to the national standards and consisted of 87 questions in 15 categories. Data were analyzed using SPSS version 19.

Results: The average rates of observance of safety and maintenance standards of diesel generators in 111-question standards and 87-question standards were equal to 61.4 and 52.8%, respectively. Regarding the observance of the 19 standards, "ventilation" and "daily visits" standards with 28.94 and 96.24, respectively, had the lowest and highest degrees of observance in hospitals. There was a significant direct association between observing the standards defined for diesel generators with the number of hospital beds (P = 0.01) and the total capacity of emergency power generation by generators (P = 0.05).

Conclusions: The results of the present study indicate a low level of safety and maintenance for the emergency power systems of hospitals. These scores are not considered favorable for a system called "emergency", and if the necessary interventions are not made in this regard, in the event of natural disasters and human errors, hospitals will face numerous problems.

Keywords: Safety and Maintenance; Diesel Generator; Emergency Power; Crisis; Hospital

1. Background

Hospitals have a very serious position and a very heavy responsibility in the health care delivery system of the country. These centers pay attention to vital matters and providing and ensuring the community health owes to their proper and responsible performance. Power outage is one of the events that may occur by natural or human causes and disrupt hospital performance (1). The Islamic Republic of Iran is exposed to various kinds of natural hazards and human errors (2) such that, according to the Global Report on Disaster Risk Reduction published in 2009, Iran's risk level has been estimated at 8 out of 10 (3). Based on the available statistics, over the last 90 years, more than 120,000 people have been killed for this reason, of which 76% has been shown to be due to earthquakes (4). Another major and effective factor is occupational accidents, the most important of which is unsafe performance (imprudence). Habits related to working imprudently and in unsafe conditions are usually the result of unawareness of how to perform activities (5).

The main causes of power outage are as follows: (1) atmospheric conditions (55%), (2) natural disasters (16%),(3) capacity shortage (14%),(4) equipment failure (11%), and(5) others (4%) (1). To reduce the probability of the mentioned risks, hospitals have to provide an alternative to urban electricity called the emergency power supply system (EPSS). The EPSS refers to a system consisting of one or more alternating energy sources that can supply power to health care facilities during a power outage. One of the most widely used and main components of this system is power generators. Emergency power generators are diesel generators, except in emergencies (6).

Some causes of the disability of the EPSS in hospitals in-

clude: (1) problems with the battery starter or its cable;(2) engine fuel impurity;(3) safety defects of power switches;(4) engine mechanical defects; and (5) transfer switch defects (7). On the one hand, improper use and testing of emergency power diesel generators can cause irreversible damages to these devices and incur huge costs. Also, regarding medical equipment that is directly connected to the diesel generator power outlet during the main power outage, it is vital to note that any change in consumption will cause changing the diesel moment round, and thus, changing the output frequency and the output voltage being considered as one of the main causes of damage to electrical devices (8).

On the other hand, hospitals are large consumers of energy; statistics show that energy consumption per square meter in hospitals is much higher than in other types of service institutions (9, 10). According to a research conducted in five hospitals in Isfahan and one hospital in Tehran, this figure was estimated at 20.57 and 66 kWh, respectively, which are respectively 4 and 13 times the standard (9, 11). Also, according to a study conducted in Tehran's selected hospitals during 2008-2010, these statistics varied from 13 to 22 times the international standard (12). Energy saving can be studied from three aspects: (1) avoiding excessive consumption;(2) maintenance in desirable conditions; and (3) examining new methods or changes that create desirable results with lower energy costs (11).

Given that devices' maintenance in desirable conditions can be one of the reasons for saving power and reducing hospital costs and numerous natural and human hazards threaten the hospital emergency power system, it is worthwhile to assess the status of this system in hospitals and take the necessary measures to deal with the risks.

2. Objectives

This study has been performed to investigate the observance degree of diesel safety and maintenance standards in hospitals of Tabriz and to answer the question of "How successful will the generators be in supplying emergency power?"

3. Methods

This research is a cross-sectional study conducted in 2014. The study population was all hospitals of Tabriz, including 22 hospitals, which due to the lack of cooperation of some hospitals (because of their military and non-educational nature), this number was reduced to 18 hospitals.

To collect the data, a researcher-made questionnaire and a checklist were used, which were compiled based on the relevant national standards. The checklist and questionnaire involved 111 questions and 19 dimensions, including general standards, staff standards, building standards, wiring standards, generator standards, electricity switchboard standards, foundation standards, ventilation standards, measuring panel standards, exhaust standards, daily fuel standards, fuel storage standards, battery standards, fire extinguishing standards, daily visit standards, weekly visit standards, monthly visit standards, weekly service standards, and monthly service standards.

The content validity of the checklist was examined by 10 experts from the expert panel consisted of the facility officials of Tabriz hospitals in the four areas of transparency, simplicity, necessity, and relevance. The content validity ratio (CVR) and the content validity index (CVI) of this tool were 0.94 and 0.95, respectively [necessity in relation to content validity (CVR) and simplicity, transparency, and relevance in relation to formal validity (CVI)].

After completing the checklist (yes or no) and the questionnaires using the observation and interview method by the researcher, the data were coded, entered into SPSS version 19, and then analyzed. To describe the results, descriptive statistics, including frequency, mean, and standard deviation, were used. Also, to investigate the possible relationship between the variables, linear and multiple regression analyses were used, with a significance level of 0.05.

It is important to explain that due to the lack of sufficient documentation to meet the standards of visit (daily-weekly-monthly) and device service (weekly and monthly), an 87-question standard score, without taking into account the mentioned areas (areas 15 - 19), was also considered. In addition, the observance degree of the standards means the degree of correspondence between observations and the aforementioned standards.

4. Results

4.1. Descriptive Statistics

The statistical population of this study included 18 hospitals with 3235 hospital beds, of which 11 hospitals and 2582 beds (79%) belonged to university hospitals, and 7 hospitals and 653 beds (21%) belonged to non-university hospitals. Other information of the studied hospitals is presented in Table 1.

Table 1. Allocation of Active Beds Based on the Type of Hospital and Its Specialtya

Specialty	University Hospital	Non-university Hospital	Total Number of Hospitals	University Beds	Non-university Beds	Total Number of Beds
Gynecology	2 (100)	0 (0)	2	258 (100)	0 (0)	258
General	3 (33)	6 (66)	9	861 (58)	617 (42)	1478
Cardiology	1 (100)	0 (0)	1	254 (100)	0 (0)	254
Psychiatry	1 (50)	1 (50)	2	591 (95)	36 (5)	627

Orthopedic	1 (100)	0 (0)	1	252 (100)	0 (0)	252
Ophthalmology	2 (100)	0 (0)	2	152 (100)	0 (0)	152
Pediatric	1 (100)	0 (0)	1	214 (100)	0 (0)	214
Total	11 (61)	7 (39)	18 b	2582 (79)	653 (21)	3235

[a] Values are expressed as No. (%) unless otherwise indicated.

[b] The total number of hospitals is 19. Shahid Ghazi Hospital is structurally similar to Imam Reza Hospital.

The results of the study showed that the percentage of the studied hospitals with one, two, three, and four diesel generators were 52.7 (10 out of 19), 31.6 (6 out of 19), 5.3 (1 out of 19), and 10.5 (2 out of 19), respectively. The total number of facility staff (19 hospitals) was 127 (i.e., there was one facility official for every 25 beds).

In the item related to the capacity of fuel storage resources for generators' work, in the capacity of daily fuel resources section (for 8 hours of generator's work), 63% of hospitals (12 out of 19), and in the capacity of storage resources section (for 15 days of generator's work), 27% of hospitals (5 out of 19) observed the standards.

The location of the diesel generator building was divided into three categories, including "in-hospital", "separated by a distance of less than 50 meters", and "separated by a distance of more than 50 meters". According to observations, 42% (8 out of 19) of the diesel generator buildings were located inside the hospital, 36.8% (7 out of 19) were less than 50 meters away, and 21.1% (4 out of 19) were at a distance of over 50 meters from the hospital. Also, the longevity of diesel generator buildings was estimated to be 27 years on average, with an average standard deviation of 4.28.

Of the 19 hospitals surveyed, only 11% (2 hospitals) had maintenance contracts with a private company, and diesel generators of all the other 17 hospitals were inspected, fault was found, and maintained by the hospital's own facility staff. Also, the average age of the diesel generators in the 16 hospitals studied (due to lack of documentation in some hospitals) was 19.36 years, with a standard deviation of 2.16 years. The average performance of the diesel generators from the beginning of production in the 18 hospitals surveyed was 3434 hours, with a standard deviation of 1352 hours.

4.2. Safety and Maintenance Standards of Diesel Generators in Tabriz Hospitals

Given that there were no documents for the standards of groups 15 to 19, a standard score was calculated without taking into account these groups. According to the surveys regarding the observance of 19 standards, ventilation standards and daily visit standards with 28.94 and 96.24 had the lowest and the highest observance degrees in hospitals, respectively. Also, the total scores, by including total questions of the groups and excluding groups 15 to 19, were 61.43 and 52.87%, respectively. Table 2.

4.3. Analytical Results

In this section, independent variables such as hospital type, specialty, number of staff, and number of beds, number of generators, generator function rate, generators' average age, total emergency capacity, and number of monthly tests were tested along with the dependent variable of safety and maintenance standard. According to the results of linear regression analysis, there was a significant direct relationship between the dependent variable of safety and maintenance in 87-question standards and the variables of number of hospital beds (P = 0.01) and total capacity of emergency power supply by generators (P = 0.05).

Table 2. Measuring the Observance Degree of Safety and Maintenance Standards of Diesel Generators

Section		Number of Questions	Number of Samples	Standard Score	Standard Deviation
1	**General standards**	6	19	42.98	26.82
2	**Staff standards**	10	18 a	6.55	29.19
3	**Building standards**	9	19	47.95	20.30
4	**Wiring standards**	6	19	68.42	22.83
5	**Generator standards**	6	19	64.91	20.70
6	**Electricity switchboard standards**	6	19	56.14	20.19
7	**Foundation standards**	5	19	71.57	27.74
8	**Ventilation standards**	6	19	28.94	19.11
9	**Measuring panel standards**	4	19	76.31	19.49
10	**Exhaust standards**	6	19	32.45	22.54
11	**Daily fuel standards**	7	19	50	20.30

12	**Storage fuel standards**	5	19	40.78	31.41
13	**Battery standards**	3	19	85.96	20.23
14	**Fire extinguishing standards**	8	19	55.92	22.19
15	**Daily visit standards**	7	19	96.24	6.46
16	**Weekly visit standards**	5	19	94.76	11.23
17	**Monthly visit standards**	3	19	68.42	17.47
18	**Weekly service standards**	2	19	81.57	24.77
19	**Monthly service standards**	7	19	69.17	16.67
20	**Total score of standards 1 b**	111	19	61.43	9.17
21	**Total score of standards 2 c**	87	19	52.87	9.19

[a] The total number of hospitals is 19. Due to building proximity, two hospitals are structurally (facility staff) similar.
[b] This score contains all 111 asked questions.
[c] This score has been recorded without calculating the questions related to visit standards and service standards (areas 15 to 19) due to staff verbal feedback.

Independent variables with sig. <0.15 in the linear regression analysis were included in multiple regression analysis. Based on the results of multiple regression analysis, there was no significant relationship between the independent and dependent variables.

5. Discussion

Electricity has a significant impact on the performance of a system, especially a hospital. Emergency power safety and maintenance are highly critical. According to the research findings, 52% of the studied standards are observed in the studied hospitals, the most important discrepancies of which include the wear and tear of equipment and diesel generator building, lack of using expert workforce, insignificance in the ideas of senior managers, and lack of scientific load and experience in this field. In a study entitled "Assessing the quantitative and qualitative performance of equipment and nonstructural vulnerabilities of selected public hospitals in Tehran during an earthquake", it was found that all the studied hospitals, as well as all the sensitive, vital, and effective wards in hospital performance, enjoyed an average and sometimes a low level of safety(13). Also, the nonstructural safety of the emergency fuel system was 43%, and that of the fire detection and extinguishing system was 57% (14). Research indicated that the percentage of observing emergency fuel standards and fire extinguishing system standards was estimated at 45 and 55%, respectively, which is in line with the previous research.

The number of emergency power generators in each hospital is at least two numbers/sets of a generator, each of which meets 60% of the hospital's needs (15). Fifty-two percent of the hospitals (10 out of 19) had an emergency power generator that did not meet the standards. Delays in starting or possible problems with generators' work stoppage can cause delays or power outages in the hospital, leading to increased risk. During the study, it was found that some of these generators were also under repair, and the hospital had practically no emergency power generator.

According to the present study, there was a direct relationship between increased hospital beds and the amplified capacity of emergency power supply with the observance degree of safety standards of diesel generators, which can be due to the high capacity and proficiency of staff, more attention to the facility section in large hospitals, and using specialized foreign contractors in large hospitals. Disregarding the safety of diesel generators in small hospitals can cause great life and financial losses. Therefore, hospitals should proceed to write comprehensive instructions for the maintenance of diesel generators.

The optimal life of diesel generator equipment and buildings is 10 and 30 years in Iran, respectively, which given the average lifespan of 19 and 28 years for diesel generators and diesel generator buildings, respectively, it indicates that the diesel generator equipment and buildings are worn out, which in itself can increase the risk (13). Also, given that 78% of diesel generator buildings (15 out of 19) are located in non-standard spaces (according to the standards, the diesel generator building should be adjacent to the hospital so that its pollution is comfortable for the patient and staff, and also the horizontal distance of the generator exhaust to the hospital building should be more than 50 meters), it is recommended to build new places adjacent to hospitals or at a suitable distance from them to reduce the contaminations caused by the device in the hospital (16, 17).

The duration of the power supply for hospital uses is 24 seconds, which according to the classification, the power of diesel generators should be available in the range of 3 to 15 seconds (5 to 7 seconds on average) (15). To reduce the risks, it is recommended that the hospital upgrades the emergency power generator system or provides a sufficient number of uninterruptible power supplies (UPSs).

In a study by Janbazi et al. entitled "Accreditation and assessment of safety standards of Hajar Hospital in Shahrekord in 2011", the overall safety status of the hospital was found to be 63.50% observance(18). The observance degree for the checklist of facility section was 66.76%, for the checklist of building section was 57.09%, for the checklist of people and equipment safety section was 61.9%, and for the specific checklist was 58.71% (19). Based on the performed research, the observance degree of safety in the facility section of Tabriz hospitals was estimated at 62 and 52%. In addition, building and staff standards were estimated at 47 and 60%, respectively, where the 10% difference in building standards and facility safety is evident compared to the two studies. This difference may be due to the exclusive look of this study at the emergency power generators section. Therefore, studying the status of safety standards in all the studied hospitals is not desirable, and staff training, preparation of guidelines and instructions, reconstruction of these centers (diesel generator buildings), and increasing the number of diesel generators to reach the desired level of safety standards are recommended.

5.1. Conclusion

In sum, a score of 52.87% for safety and maintenance and the presence of a diesel generator in 52% of hospitals could not be acceptable statistics for a system called "emergency", and given factors such as human error, natural disasters, including floods and earthquakes, and overload, in some cases, the possibility of timely availability of emergency power system is reduced. To achieve the required standard regarding emergency power supply to hospitals, arrangements must be made such as standardizing the number of generators, securing their location, training staff, and preparing instructions. Given that the observance degree of the standards is directly related to the number of beds, this key issue requires the attention of health policymakers to small hospitals with fewer beds.

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