

Allied Performance of Hospital Lifelines and Emergency Actions during East Japan Earthquake



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SUMMARY:

Present paper treats the field investigation of hospital yards and interview to 3 main hospitals in Miyagi Prefecture where severe damage occurred due to ground motion and Tsunami attack in the 2011 East Japan Earthquake. Relation between emergency performance of hospital lifelines and the number of medical care patients was investigated.

Keywords: 2011 East Japan Earthquake, hospital, lifeline, patient, emergency response

1. INTRODUCTION

March 11, 2011 East Japan Earthquake caused earthquake magnitude of world's largest scale M9.0 and Tsunami along the shore line of Iwate, Miyagi and Fukushima prefectures. As a result, the victim reached up to over 20,000 people, and the house damage exceeded about 1 million. Furthermore, there are a lot of cases which lost human life that could be saved without the malfunction of lifelines such as road, electric power, water and so on.

Damage of hospitals during the earthquakes gave serious effects to emergency medical care of victims by earthquake attack. The physical and function damage of hospital are divided into buildings, lifeline equipments within hospital buildings related to city supply lifelines and medical care apparatus. Takada and Kuwata (2006), Miyajima (2007), Ikeuchi (2007) have investigation on hospital lifeline damage during recent earthquakes and measures to keep function for emergency medical cares.

Present paper treats the field investigation of three hospitals in Miyagi Prefecture where severe damage occurred due to ground motion and Tsunami attack. Two of which were located very near to Tsunami area. Hospital lifelines had severe physical and function damage in water pipe network, waste water pipe, power, gas and telecommunication and access road to hospitals. Performance of lifelines was influenced mutually by other lifelines, and interruption of lifeline service had a great influence on medical care.

This paper addresses the damage of hospital facilities and also lifelines inside and outside the hospitals, and the change of number to accept patients. In addition, this paper addresses the relation of restoration process of lifelines and the acceptant number of inpatients.

2. OUTLINE OF THE EARTHQUAKE AND DAMAGE

2.1 Outline of the earthquake

A historical largest earthquake with M9.0 in Japan occurred approximately 24km in depth off Miyagi Prefecture coast line (Epicenter: 38.1 degrees N, 142.9 degrees E) occurred at 14:46 on March 11, 2011. The earthquake calamity was of serious damage such as 15,866 victims, missing person 2,946, injured person 6,108, complete destruction of houses 130,441, partial destruction of houses 263,002, house of 717,797 some damage occurred(Data at June 27, 2012).

2.2 Intensity of earthquake

In Miyagi Prefecture, the maximum seismic intensity 7 (JMA) was recorded in Kurihara City by this earthquake, and 6+ in coastal area around Sendai City and inlands of Tome City, Osaki City and so on. Seismic intensity 6- was recorded in wide area in Miyagi Prefecture. Fig.2.1 (a) shows seismic intensity distribution in Miyagi Prefecture by Meteorological Agency information and the position of the three hospitals. The seismic intensity in each three hospitals was 6-.

Figure 2.1(b) shows the maximum acceleration time histories in Sendai City, Shiogama City and Ishinomaki City. The wave pattern is characterized by two main shocks and the first wave was observed at about 14:47, and the second wave was recorded at approximately 1 minute later. The maximum acceleration in three cities was 1,969gal in Shiogama City where Saka General Hospital is located, 1,517gal in Sendai City. The arrival of the earthquake wave was the earliest in Ishinomaki City.

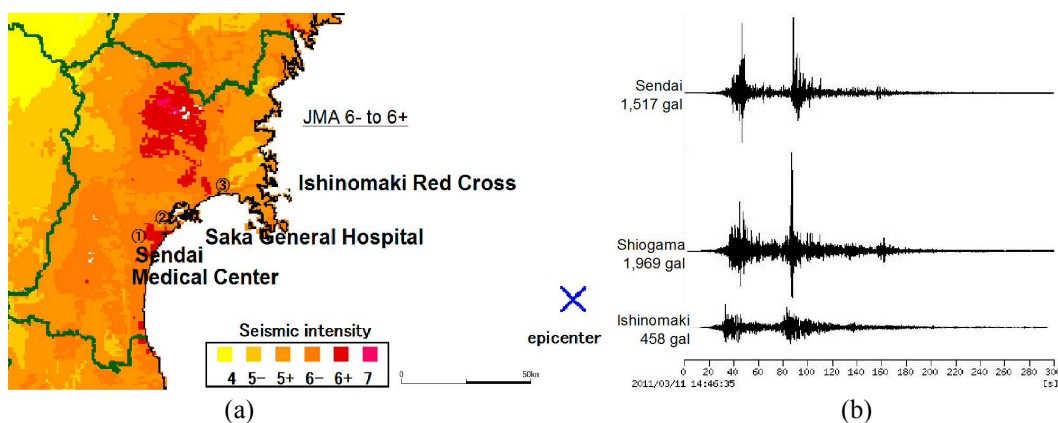


Figure 2.1 (a) Intensity of ground motions by JMA in Miyagi Prefecture

(b) Maximum acceleration in three cities [NIED]

2.3 Tsunami flooded area

Tsunami was generated widely in a coastal area, and there existed areas apart 5km from the shore lines were attacked by Tsunami. In addition, Tsunami inundation damage increased around a river by the Tsunami having rising up along river. Each three hospital which we investigated was near to the Tsunami area, but barely avoids inundation damage.

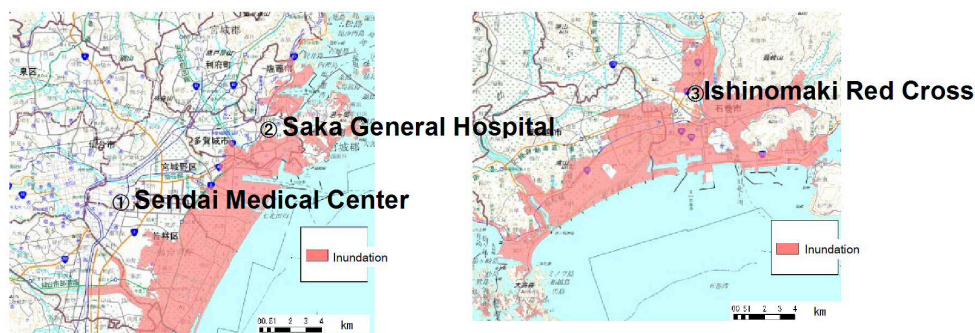





Figure 2.2. Tsunami flooded area and the position of three hospitals [GSI]

3. DAMAGE OF HOSPITALS AND LIFELINES

3.1 Outline of three hospitals

Outline of three hospitals is shown in Table 3.1. Each hospital was established in the early 1900s. Each hospital has 357-698 sickbeds, and the number of doctors and nurses is approximately 340-600 persons. The hospitalization number of inpatients is approximately 300 people per day and outpatients 200-900 people per day. These hospitals are the largest hospitals in Miyagi Prefectures.

Table 3.1 Outline of three hospitals

	①Sendai Medical Center (Sendai city) 	②Saka General Hospital (Shiogama city) 	③Ishinomaki Red Cross (Ishinomaki city) 
Establishment	1937	1912	1926
Number of bed	698 bed	357 bed	402 bed
Number of doctor and nurse (2009)	Doctor: 141 Nurse: 462	Doctor : 75 Nurse : 262	Doctor : 90 Nurse : 382
Averaged number of patient (2009)	Inpatient: Outpatient : 918/day	Inpatient : 333/day Outpatient : 219/day	Inpatient : 371/day Outpatient : 893/day
Medical department	26	25	27
Others	<ul style="list-style-type: none"> •Disaster base hospital •Critical care center •Being bombed medical institution •DMAT Designation medical institution 	<ul style="list-style-type: none"> •Disaster base hospital •DMAT Designation medical institution 	<ul style="list-style-type: none"> •Disaster base hospital •Critical care center •Being bombed medical institution •DMAT Designation medical institution

3.2 Damage of hospital facilities

The main damages of the facilities in the hospitals are the break of the water tank at their roof, the trouble of chlorine infusion facilities for water, a leakage of water in-hospital pipe. Other damage was exfoliation of outer wall of building and leakage of sprinkler pipe and pipes connected medical care apparatus.

Table 3.2 Damage of hospital facilities

		①Sendai Medical Center (Sendai city)	②Saka General Hospital (Shiogama city)	③Ishinomaki Red Cross (Ishinomaki city)
Building	Building year	Seismic retrofit from 1998	Move to new building at 2005	Move to new building at 2006
	building・floor	11buildings・6floors	1 building・10floors	1building・7floors
	Area of space	64,395㎡		69,816㎡
	Area of building	21,274㎡		10,173㎡
Major damage of facilities inside hospital	Water supply facility	<ul style="list-style-type: none"> •Break of panels of water tank on rooftop in 3 buildings •Water leakage of water supply pipe in base floor 	<ul style="list-style-type: none"> •Collapse of water tank on rooftop •Break of chlorination facility 	
	Medical care equipment		Break and water leakage of ICU pipe	
	Drainage	Sink of manhole		
	Others	<ul style="list-style-type: none"> •Water leakage of fan-coil unit •Damage of sprinkler pipe •Damage of vapour valve or pipe 	<ul style="list-style-type: none"> •Damage of outer wall and interior decoration of hospital •Break of sprinkler 	

3.3 Damage of hospital lifelines

3.3.1 Sendai Medical Centre

Tohoku Electric Power stopped just after the earthquake occurrence of March 11, but self oil generator and gas generator were used up to the coming back of power on the midnight of March 13. There was no effect by the stop of city water by using self well -water in hospital with the aid of pumping up by generator power. However, severe effects occurred for maintaining medical care system due to damage of water supply facilities such as water tank at rooftop. Gas stop during two weeks gave large effects to make boiling water, cooking and so on. Especially, water stop gave important effects to medical care system which forced patients to move to other hospital, malfunction of emergency medical center and care for outpatients. It took about 40 days up to April 18 to come back to normal care system.

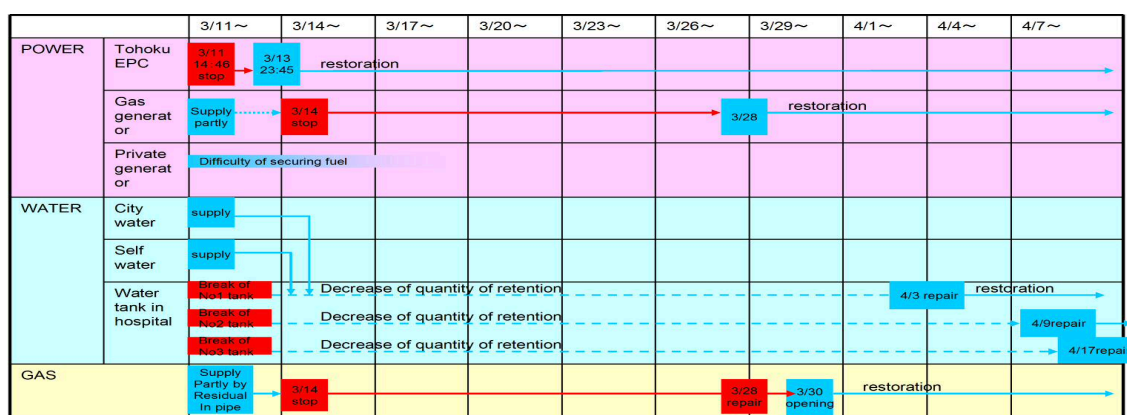


Figure 3.1 Damage of hospital lifelines in Sendai Medical Centre

3.3.2 Saka General Hospital

Electric power stopped just after the earthquake. However the generator could cover the power up to March 14 when power restored. Oil fuel had been prepared for five days operation. It took three days to use CT, MRI and elevators due to power outage. The effects of water supply stop by city water were not so severe due to usage of self well -water in hospital covering 95% of necessary water volume. Self water system could start after 14hours from the occurrence of earthquake though the system had damage in water tank. Telephone and mobile phone could not use just after the earthquake. Transceiver was used inside a hospital building. Satellite phones were used after three days. Oil fuel was the key material for operating backup systems. Satellite phone and self water supply system are also necessary in emergency response.

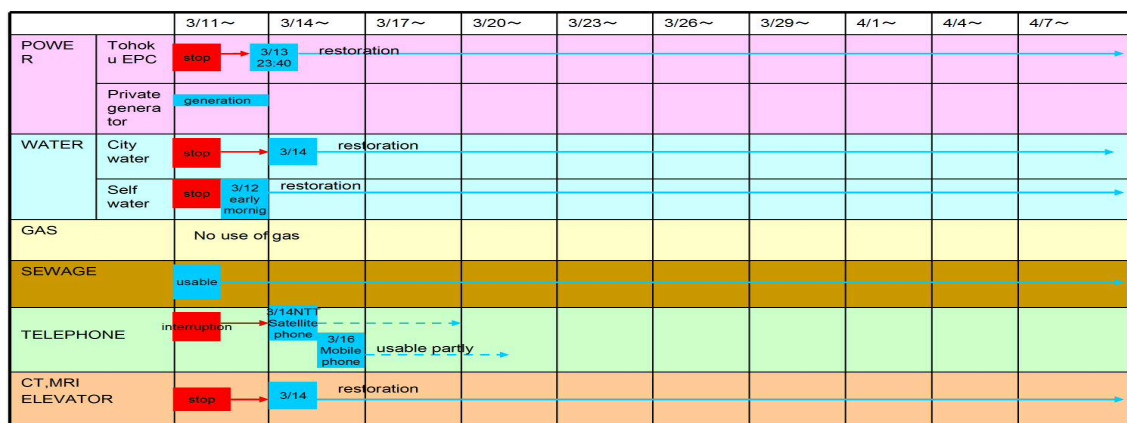


Figure 3.2 Damage of hospital lifelines in Saka General Hospital

3.3.3 Ishinomaki Red Cross Hospital

Electric power stopped just after the earthquake. However self generator covered the most of the necessary power up to March 13. The oil fuel was almost limited for usage due to insufficient preparedness. City water supply stopped after earthquake. However water inside tank covered the three day necessary water owing to saving water. After that, emergency water supply by city water could use for necessary water in hospitals. Self water -supply system could not use due to no function of chlorine infusion. City gas supply stopped after earthquake giving difficult conditions for cooking and others. Temporal gas generator (low pressure gas) devises were used during March 14 to April. General telephone and mobile phone could not used. However, special lines for disaster management phone worked well. No damage occurred in hospital buildings and quick recovery of power/gas and water did not give serious effects for emergency medical care. However, stop of telecommunication gave a lot of difficulty.

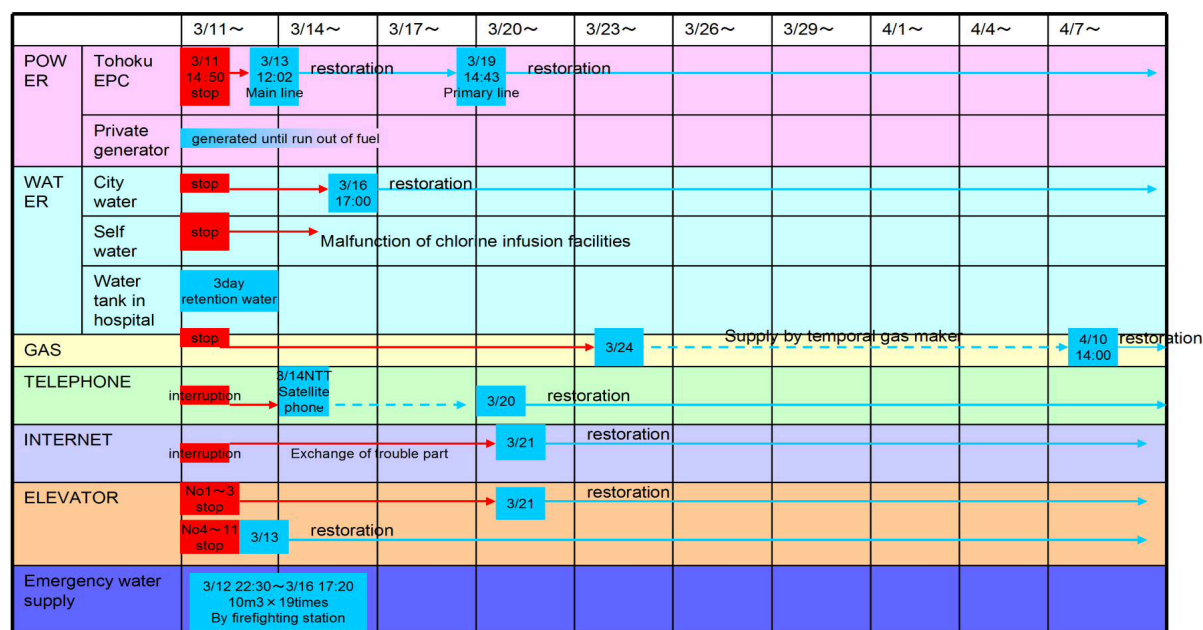


Figure 3.3 Damage of hospital lifelines in Ishinomaki Red Cross Hospital

4. EFFECTS TO EMERGENCY MEDICAL CARE

4.1. Sendai Medical Centre

About 600 inpatients were in hospitalized at the time of earthquake. However, due to malfunction of water supply, the patient number decreased down to 334 continuing to April 3. The outpatient number on March 11 was about 700 before the occurrence of the earthquake. The outpatient number became 100~300 during March 12 to 22. After that, the number was 700~800 besides of Saturday and Sunday. The number of triage was mostly 705 during March 11 to 16 within outpatients. These are shown in Fig.4.1. 65 patients on March 11 gradually increased to 163 patients in March 15. Then decrease to 66 on March 16, Total 705 patients during Triage period. Other hospital accepted serious patients and 4 patients of Red tag patients on March 18 and 19. Within total number 713 of triage patients: Black tag: 3(0.4%), Red tag: 71(10%), Yellow tag: 233(32.7%) and Green tag: 406(56.9%) during March 11 to 19. These are shown in Fig.4.2.

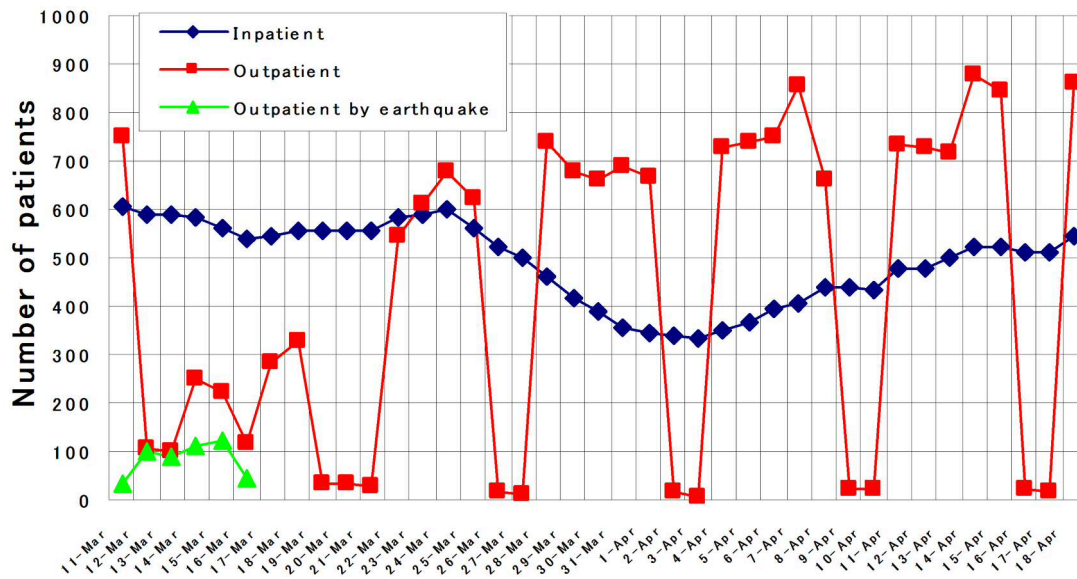


Figure 4.1. Change of patient number in Sendai Medical Centre

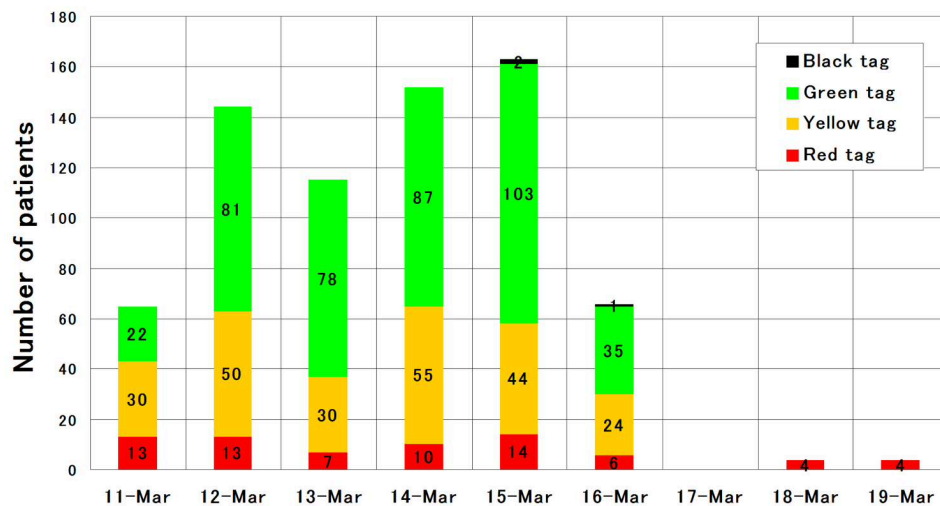


Figure 4.2 Change of triage patient number in Sendai Medical Centre

4.2. Saka General Hospital

Within total number 2372 of triage patients: Black tag: 11(0.5%), Red tag: 185(7.8%), Yellow tag: 880(37.1%) and Green tag: 1296(54.6). The ratio of triage tags is similar to ones in Sendai Medical Center. Within triage patients, Inpatients: 304, Emergency transportation: 311 and Operation:16. Outpatients were small on March 11 and the maximum number 240 was next day of March 12. The number of out patents decreased down to 180 on March 22 after 10 days. Many outpatients were coming after that. Number of patient treatment was max of 48 in Respiratory and Digestion, in Pediatrics, and in Glucose metabolism, Circulatory organ department. Inpatients are over 50% in 70~90 age generation person and the maximum percentage is in 70 age generation person. These are shown in Fig.4.3 and Fig.4.4

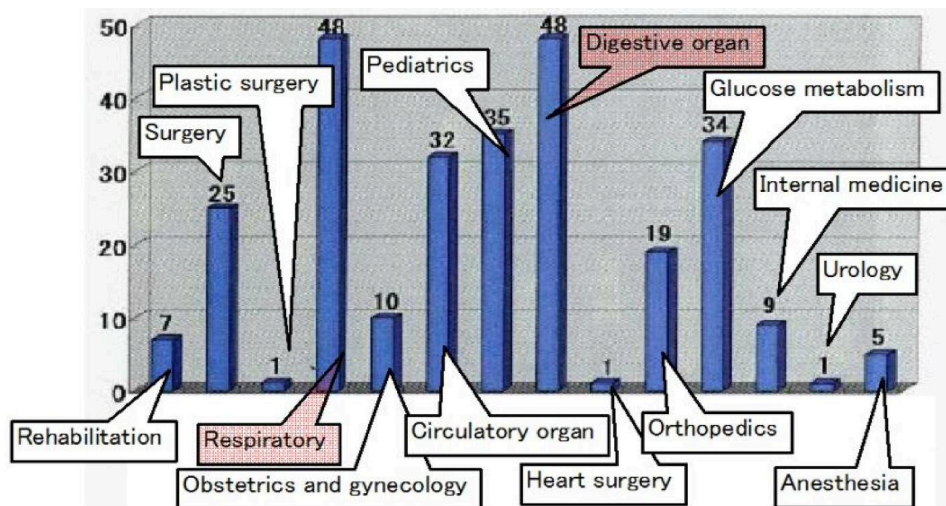


Figure 4.3 Inpatient number at medical department

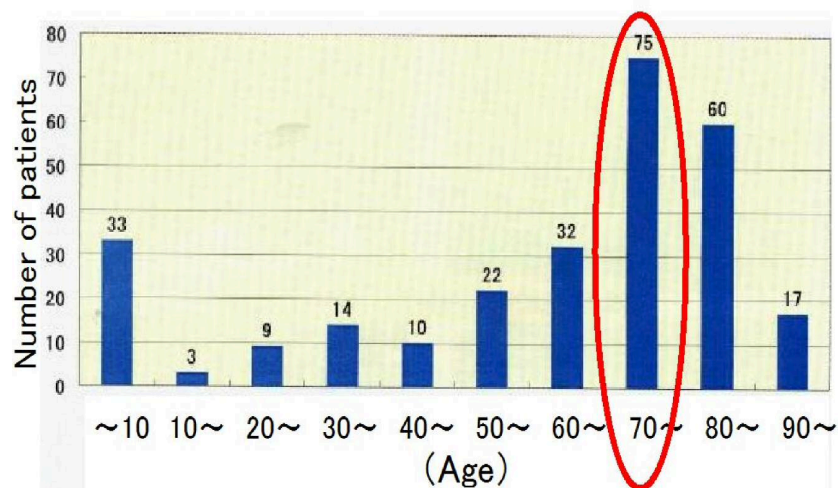


Figure 4.4 Inpatient number by age

4.3 Ishinomaki Red Cross Hospital

The maximum number of patients became 59 at hospitalized ones on the next day of March 12. After that, hospitalized patients decreased gradually and 25 patients on March 16. However, the number of patients became larger on March 20 and averaged number was 30 patients in April and May. The number in June was 34 patients in average. 40% of total outpatients were in emergency treatment on the next day of March 12. These are shown in Fig.4.5.

In March, inpatient number is most in respiratory, internal medicine in emergency treatment department. However, in April to June, internal medicine is most, and next is respiratory and circulatory organ department. These are shown in Fig.4.6. Triage patient number became maximum 1,251 after two days of the earthquake. It decreased to 300 on March 16. These are shown in Fig.4.7. Total number of outpatients was 19,800 during March to June. Within that, Black tag: 220 (1.1 %), Red tag: 2,674 (13.5%), Yellow tag: 11,742 (59.4%) and Green tag: 5,118 (25.5). The ratio of triage tag color is different from Sendai Medical Center and Saka General Hospital. The yellow ones were higher.

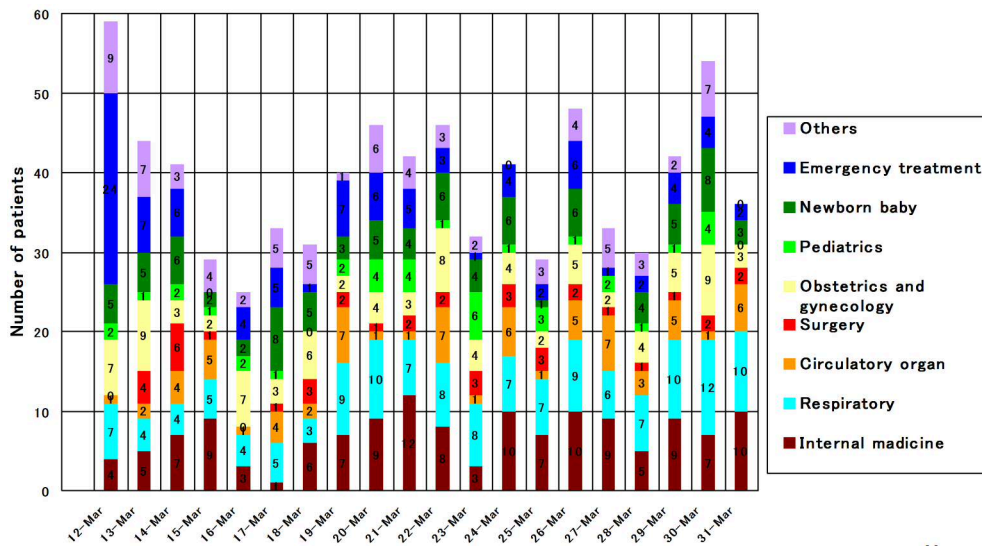


Figure 4.5 Change of inpatient number in March

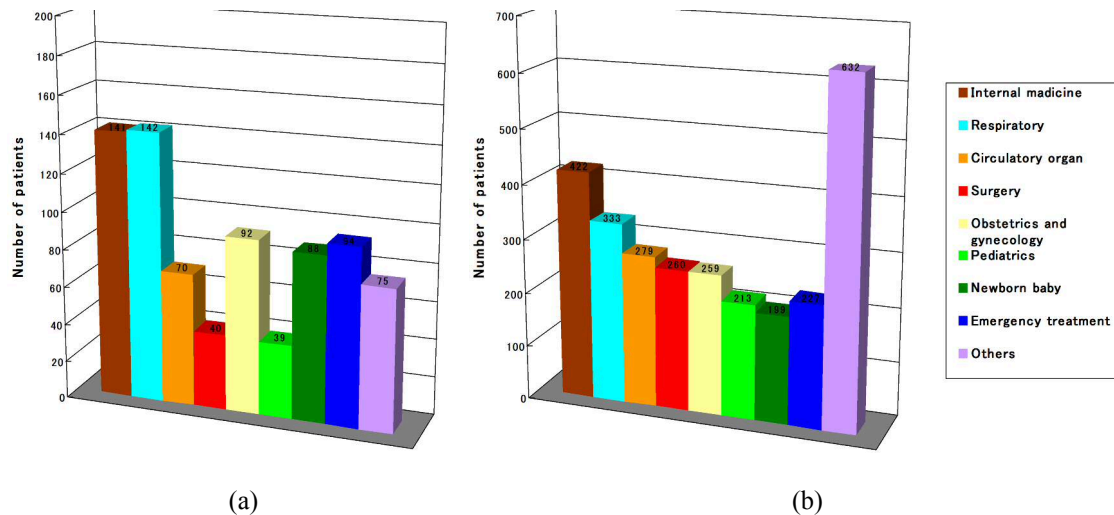


Figure 4.6 (a) Inpatient number at medical department in March

(b) In April to June

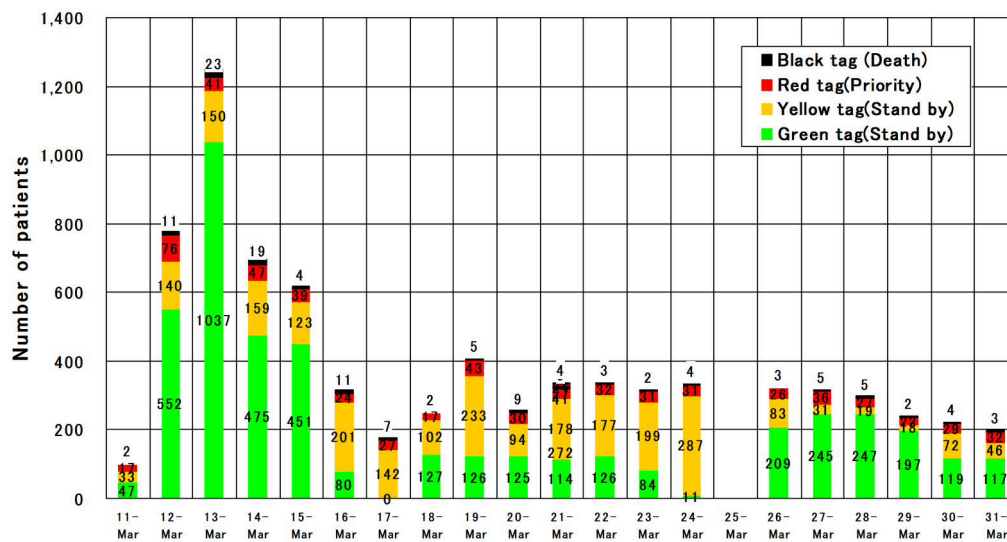


Figure 4.7 Change of triage patient number in March

5. RELATION BETWEEN RESTORATION OF LIFELINES AND INPATIENT NUMBER

5.1. Sendai Medical Centre

Relation between restoration of lifelines and inpatient number in Sendai Medical Centre is shown in Fig.5.1. Just after the earthquake occurrence, power and water were available by operating backup system such as private generator and well -water. Therefore, inpatient number hardly decreased. However, the inpatient number gradually decreased from March 25 to April 3, because the intake of large quantity of water was required by the damage of water tank on rooftop by having regulated the hospitalization number of patients. After that, inpatient number increased with a water tank having been restored on April 3 again because of stable water supply.

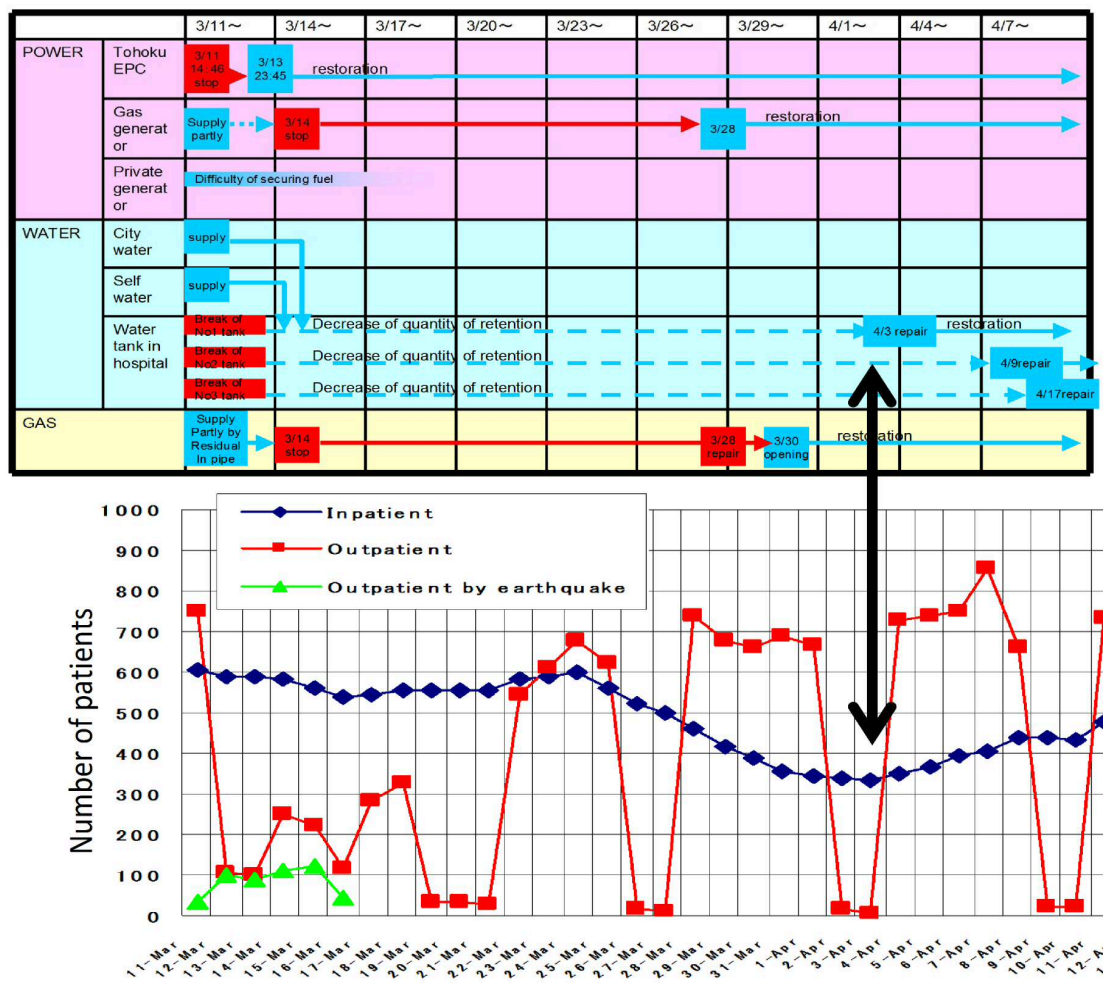


Figure 5.1 Relation between restoration of lifelines and inpatient number in Sendai Medical Centre

5.2. Ishinomaki Red Cross Hospital

Relation between restoration of lifelines and inpatient number in Ishinomaki Red Cross Hospital is shown in Fig.5.2. Just after the earthquake occurrence, power and water were available by operating backup system such as private generator and retention water in the tank having capacity of three days. However, because city water supply stopped and chlorination facilities trouble occurred in hospital well -water, the difficult situation depending only on water supply by emergency water wagon continued until March 16. Meanwhile, inpatient number continued decreasing below by half from 59 people of March 12 on the next day of the earthquake occurrence up to 25 people, but inpatient number increased again from March 17 on the next day when city water was able to restore in the evening of March 16.

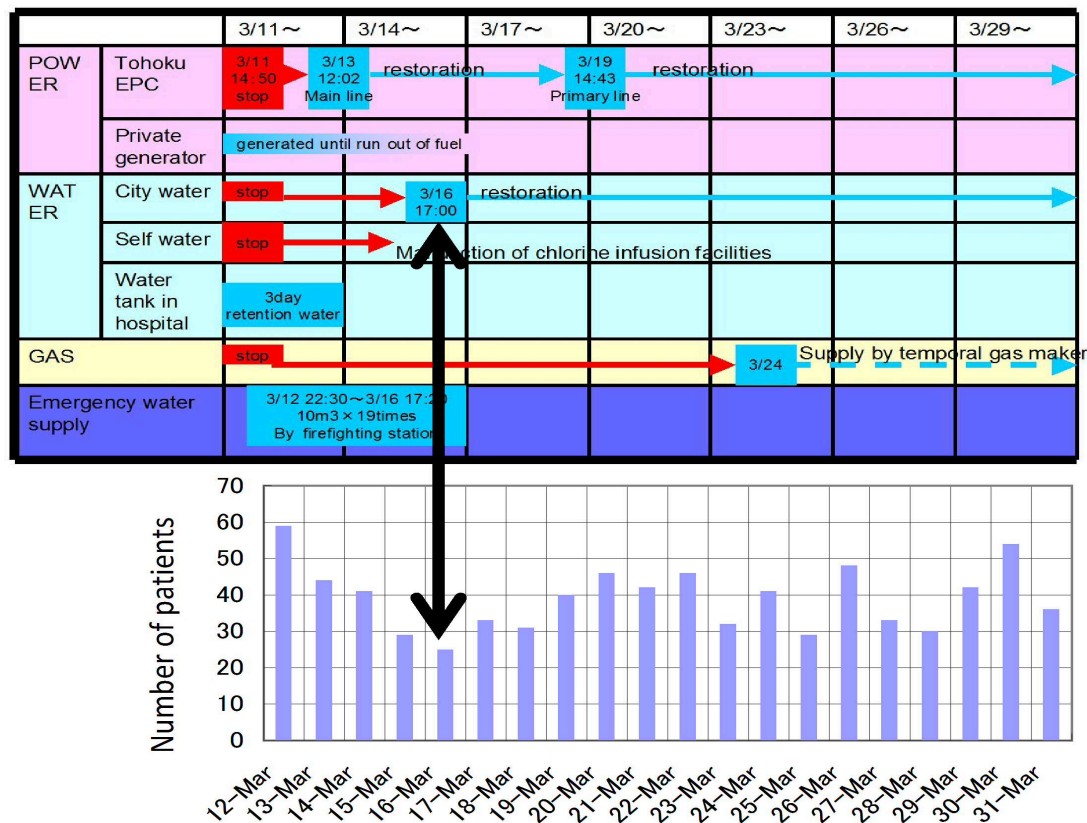


Figure 5.2 Relation between restoration of lifelines and inpatient number in Ishinomaki Red Cross Hospital

6- CONCLUSION

Malfunction of lifelines such as water, power, gas, telecommunication, road and railway systems have made difficulty of quick restoration and have caused lose of human life which would be saved when it was working without disrupt of these facility function. Activities in three hospitals near to Tsunami areas which accepted many injured persons and did emergency medical care under malfunction of lifeline function were investigated and summarized important lessons. Especially, water stop gave important effects to medical care system which forced patients to move to other hospital stopping emergency medical center and care for outpatients. Even in hospitals where well-water was working under without city water, oil fuel was the key material for operating generators as backup systems. Satellite phone and self water supply system are also necessary in emergency case.

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