Development and Application of IT Triage System (TRACY) for Sharing Disaster Medical Information During Large-Scale Disasters

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SUMMARY
This study develop a triage system which can collect, automatically update and share the disaster medical information in real-time among hospitals both inside and outside the disaster area, with residents and with the government. In selecting the device of this system, simple, daily basis and low-cost were discussed. According to these points, FeliCa card can be applied to the triage system. Because the FeliCa card is very popular in Japan for the train pass, electronic money, and so on. The operation is simple "waving the card to the reader" and there is potential to be expanded further. The present system showed the high possibility to get the number of patients in each triage level in real-time, to identify the number of patients in each department, to manage the triage level changes in real-time and to share this information with related institutions across an entire region by the disaster drill.

Keywords: triage, disaster management in hospital, TRACY, real-time information, information sharing

1. INTRODUCTION

Disaster medical care during accidents and disasters both large and small is carried out with less medical resources in normal situations. Disaster medical care consists of triage, transport and treatment. In the case of a disaster or accident, it is necessary to exert maximum effect with limited medical resources, but to accomplish these hospitals need to estimate the expected number and condition of patients. The advancement of triage, including understanding and ensuring the capacity of beds, tracking the status of patients' visits and transport to other hospitals, managing the assignment of the appropriate medical staff and the distribution of medical materials is necessary. On the other hand, information sharing is important effective acceptance and transportation. These actions are required across the entire region outside the hospital for setting up the disaster headquarters, coordinating all tasks with the government and other hospitals, and supporting the patients' family and media.
To advance the triage, it is necessary to obtain patient information, such as the victim's status and number staying at hospital, discharging from hospital, and being transported to other hospital, in digital form and in real time.
Research using a digital pen with triage results can digitize patient information (Ashida et al. 2008). However, it is difficult to manage patient status when triage level is changed and to understand the number of patient in different triage levels. In addition, the usage of RFID tags and mobile RFID network equipment collection system can collect the patient information using mobile devices in real time (Sonoda et al. 2007, Kusuda et al. 2009), but it is necessary to overwrite data when the triage level is changed so the management is complicated. Furthermore, the flow line of patients cannot be confirmed when patients are moved between departments.
For information sharing across an entire region, an information sharing system has been built to consolidate all kinds of information related to disaster conditions (The Ministry of Health and Welfare

Health Policy Bureau 1996). With this system, staffs are necessary for entering the data in this system, but it is difficult to assign staff under the limited conditions during a disaster.
The purpose of this study is to develop a triage system which can collect and share the disaster medical information in real-time among hospitals including emergency medical institution both inside and outside the disaster area, with residents and with the government. In order to examine the feasibility and effectiveness of this system, it was applied to a large-scale disaster drill with 450 participants at the Yamanashi University Hospital.
Using this system, it is possible to estimate the number of patients in different triage levels in real time, to identify the number of patients visiting each department, to manage the triage level changes in real time and to share this information with related institutions across an entire region including people looking for their family in hospitals.

2. PROBLEM SETTING

Traditional triage problems are summarized from the result of the triage drill held at Yamanashi University Hospital.

2.1. Summary of triage

A triage team normally consists of the triage officer, nurse and support staff. The team conducts the triage in front of the hospital building. Patients taken to the triage are transferred to the treatment zones: the mild zone (green), the moderate zone (yellow), the severe zone (red) and death zone (black), depending on the level of injury. If the hospital cannot treat the patient with heavy injuries or due to lack of resources, the patient is transferred to another other hospital.

2.2. Problems of triage

The following problems with the current triage method were obtained from the result of the triage drill at Yamanashi University Hospital.
It takes a certain amount of time for the disaster headquarters to know the latest patient information such as the number of accepted patients and the number of patients in the different triage levels because the copy of the current triage tag containing patient information such as name, age, etc. and triage level is carried by volunteer staff to the headquarters after a certain amount of information is collected in each zone. Furthermore, it takes time to copy the information to the patient's list handwriting one by one. In addition, patient information is written on a white board in front of the hospital near the triage zone to for people looking for their family in hospitals.
Therefore, it is difficult to grasp the number of patients in real time and assign the proper medical staff to the each zone in this triage method. When there is a change of triage level, the management of its change is very difficult to update in real time. Also, some staff needs to work only for the management of patient's list. It can be wasted work under the limited resources of medical staff in the disaster.
It is necessary to determine that; the patient needs to be transferred to other hospitals by such as the doctor helicopter, because of the heavy status of patient or the luck of hospital's resources. However, hospitals which need to transfer the patient cannot make a plan of transference of patient. Because hospitals don't know which other hospitals can accept the patient. On the other hand, the accepting hospital management also doesn't understand the status of coming patients.
The information sharing among related medical institutions is necessary for the effective transport in the entire region.
The people look for the location of hospital in which their family is accepted due to the injury in the disaster. The hospital and the government asked by the people need to answer the location of hospital and the status of the family.
However, immediate response is difficult for the hospital in a situation of a huge number of patients. Because they cannot search the patient whom the family looking for in the paper-based patient's information and it takes a certain time to obtain the latest information.
In the point of the local government, even if the government needs to find the family where they are,

the local government has to ask the possible hospitals one by one.
This situation is inefficient for all the relations, the family, the hospital and the government.

3. IT TRIAGE SYSTEM (TRACY)

TRACY has been developed as the triage system to solve the traditional problems observed in the result of triage drill and the things discuss as mentioned above. The structure and framework of this present system has been set after several interview and meetings with doctors and nurses in emergency department. This section describes the overview of this system.

3.1. System framework

We discussed the obtaining patient's information in real time and the sharing it in the whole area as main features. The obtained patient's information including the location, triage level and status of patient need to be updated in real time. It is effective and efficient to share the information for the patient transference to the other hospital. On the other hand, there are some advantages in traditional triage tag. When we need to know the patient's information such as name, age and triage level, the current triage tag can show those by seeing it without special operation. Therefore, both present system and current paper based triage tag are used.

3.2. Management of triage level changing

We discussed when the triage level change the information about triage level also should be changed without special operation of the system in real time. If there is a change of triage level of the patient such as patient moves to the new triage zone. When the patient arrive the entrance of the new zone, we proposed that the change can be recorded by the usual pass-processing used in present system. This method can update the triage level automatically without special and/or additional work. This method also can confirm the movement of the patient correctly.

3.3. Patient's family

To respond quickly to the people who are searching for their family member in the hospital, the staff can search the patient by using the search function of present system in the patient list. In addition, if the list can share in the whole area, it is beneficial for the government and the family living far from disaster area.

3.4. Sharing of patient information for transportation

We discussed that it is important to conduct the effective transporting in the entire region. This could be done by understanding the condition of accepting patients in other hospital and then to decide whether the transporting is available. Therefore, the present system is required to show the condition of all related hospitals to decide the available transportation in the entire region.

3.5. Discussion of equipment

The following three points in selecting the equipment for this system were considered. 1) Using the equipment on a daily basis, because other than daily-life equipment does not work in a disaster. 2) Using low-cost equipment in order to spread to the lot of hospitals under the current economic condition for sharing information in entire area. 3) Using simple-operating equipment that is not required the special training for operation only for the disaster.
First, we discussed a handheld wireless UHF IC tag reader/writer that can write the patient information to the tag. But when the medical staff try to know the patient's information in the IC tag, the special operation is required. In addition to that, for the sharing information of patient in the entire area, same equipment is necessary to install in all related hospitals. In the consideration of cost, the writing

function of the patient information to IC tags/cards is not the low-cost option.
Therefore, the concept of this system is to manage the patient's information in the server side. Then, the three method, IC tag, bar codes and FeliCa, were discussed how to recognize the patient ID. The IC tag is expensive, even for the models without the function of a tag writer. For bar codes, we have to consider the accuracy of reading the bar code, the preparation of bar codes in advance and the problem of cost. As the result of these factors, the bar code is actually difficult to apply to the management of patient for triage. For FeliCa, USB-friendly FeliCa reader can be purchased at lower prices. It is available to use the PC, which is used on the daily treatment in hospitals, for connecting it. In addition, FeliCa cards are used by a lot of people for the train pass, student ID, and electronic money on a daily basis. Recently, there is also mobile phone with a FeliCa function. Therefore, FeliCa can be applied on a daily basis to conduct the triage in the disaster. The operation is simple "waving the card to the reader" and there is potential to be expanded further spread.
From the above discussions, FeliCa is used as the configuration of the equipment in this system.

3.6. Constitution of "TRACY"

There are advantages by applying FeliCa on the daily basis to the triage. For example, the database of the personal information such as name, date of birth and address for the daily service can be applied for the triage to recognize the each patient in the disaster by using FeliCa ID. In this case, the hospital is not required to ask the patient for the personal information and can be understand the patient personal data who cannot speak due to heavy injury. As there are many people who have the FeliCa for daily service, therefore hospitals are not necessary to ready the FeliCa card in advance for all unpredictable large number of patients.
The unique serial number of FeliCa can be considered as the patient ID. Therefore the hospitals and other related institution can easily share and manage the patient transfer by using FeliCa ID for the entire region.
Figure 1 shows an overview of this system. FeliCa reader and PC for pass processing are set at triage zone and each zone such as Black (deceased), Red (immediate), Yellow (delayed) and Green (minor), and the department of medicine and radiation. PC and FeliCa reader at the each point for pass processing can record the patient's zone pass time and location in the database server.
In the case for example, that the symptoms of patient is changed to the worse, the latest triage level can automatically be update in database server without special work or operation by conducting the usual pass processing in this system. This is same case, even if the symptoms improve.

3.7. Content of input item

We consider following kinds of information are necessary for triage in TRACY.
From the hospital point of view, patient personal information and medical information are taken in to account as patient detail. But this triage system only covers the personal information (name, gender, date of date, etc.) but not medical information. Because misunderstood medical information may lead to medical errors and troubles.
As the result, input items of personal information such as name, date of birth, age, address, and free entry for the remarks are read with the triage tag. One example of using remarks is to write the patient exterior features such as the colour of shirts, jacket, glass etc. to identify an individual who cannot speak due to heavy injured.
There is high possibility to stay or transfer to other hospitals for the patient with the level of Red (immediate) and Yellow (delayed). In case of those, the room or building of staying and the hospital name of transferring can be entered in this system.
The interface of the personal information window was made considering easy to be used by hospital staffs.

3.8. Visualization of patient data at the headquarters

It is important for the forward-command-headquarters directing the assignment of medical staff and the emergency-response-headquarters to take a proper action to manage the triage work based on

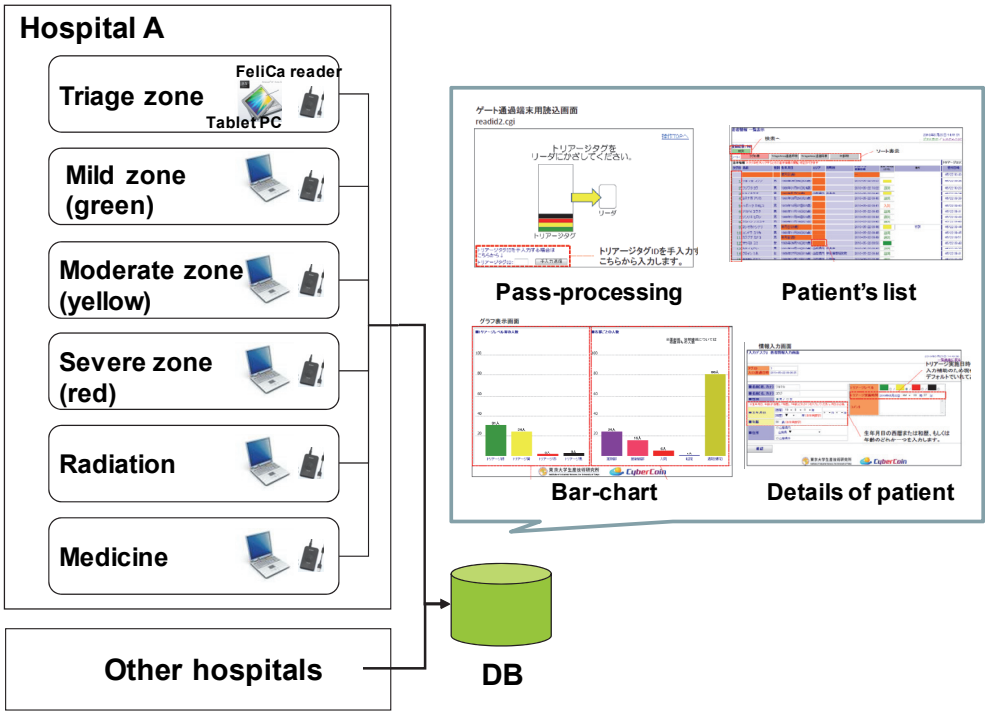

Figure 1. Overview of triage system "TRACY"

understanding the situation such as the number of current accepted patients in the hospital, the number in the different triage level for each treatment zone in real time.
We discuss how to show those data in present system. As the result, the bar-chart showing the patient number in different triage level and the all patient list are necessary to analyse the condition of hospital for the triage officer at the both headquarters. The chart and the list can be updated automatically every 5 seconds. When the patient's information is needed to edit, the details window of patient is available from the list of patient.

3.9. Preparation of the system

When a disaster occurs, the system must quickly starts with a minimum preparation of work as much as possible.
The present system is developed on the CGI (Common Gateway Interface). This system can work by the PC which can use WEB browser, is independent of PC type, and doesn't need any additional installation. The CGI program that runs on the WWW-server is independent of PC type/ OS and it can be work by the access form the browser of PC for pass-processing at the each zone. The result of the working of CGI returns to the browser of each PC at the zone.
As mentioned above, the digitize the patient information by FeliCa in real time can achieve not only the advancement of triage such as tracing of the patient treatment but also the sharing patient's information such as the transfer to the other hospitals, quick response to the person who asking of his/her family's location and coordination with the administration for the entire region.

4. VERIFICATION OF TRACY BY DEPARTMENT OF YAMANASHI UNIVERSITY HOSPITAL

The Yamanashi University Hospital in Yamanashi prefecture has experienced the triage drill since 2001. This triage drill becomes 10 times in total. The purpose of this drill is that the hospital staffs makes accurate safety, accept the patient, implement triage and handle the treatment when the big earthquake occurs in Yamanashi prefecture.

The present triage system, TRACY, was examined its availability and practicality in the real disaster by applying the triage drill on this hospital with enough experience.

4.1. Triage drill of Yamanashi university hospital

In this triage drill, 48 doctors, 21 medical engineers, 48 nurses, 47 office staffs, 145 patients and support staff, totally approximately 450 people were attended. Participants were not only from this hospital, but also from the other hospital, the fire station, the government of Yamanashi Prefecture, the government of Kofu City, the government of Central City and residents.
The drill assumes the disaster level that, there is damage in the hospital building, but the lifeline and other medical equipment work normally. Therefore the triage and treatment are available even for a large number of visiting patients.
At 9:00 am a big earthquake with the epicenter of the west and southern area in Yamanashi prefecture caused a damage of houses, a fire and a traffic accident around the hospital. Then the staffs in the hospital check the status of the building damage and secure the safety of responsible department based on the disaster manuals and according to the instruction of the leaders of each department. All staff prepares to accept the number of patients as soon as possible. The team of triage set the necessary materials in the front of hospital building and to decide the triage level of each patient on the symptoms. After triage, the patient moves to the triage zone or is transferred to other hospital depending on the triage level.

4.2. Outline of installation of system

The PC set at Triage area in the front of hospital building, each triage zone, each treatment department and headquarters. **Figure 2** shows the PC and FeliCa reader set at Department of Radiology. FeliCa cards is adhered to the back of triage tag, and managed to integrate triage tag and FeliCa cards together. As the reader of FeliCa card, the FeliCa port/ pasori (RC-S320) which is compatible with USB was used.
In this triage drill, FeliCa card has not been entered personal information such as name and date of birth, and assuming a situation in which these information was enter at the hospital. As for the timing and the person who enter the personal information, the patient information is input at the upstream process of triage to answer the person who asking from patient family as soon as possible. The special person who only input the patient data are assigned beside the doctors, nurses, clerks separately. By this way it can solve the problem that the patient cannot move during the entering their triage result or personal information in present system. In the case of a large number of patients compared with the number of staff for data input, even if all the data entering is not completed, the personal data can be registered on a temporary basis, and then all staff can modify or update the content of the personal data at the each triage zone or headquarter.
All four triage teams consisted of triage officer (doctor), nurse and support staff (clerk) at the triage area. The triage officer and nurse carry out usual triage work same as traditional triage way. On the other hand, the clerk read the FeliCa card to recognize its ID by Felica reader connected to the mobile PC by USB. Then clerks give the triage tag to triage officer, when just before triage officer begin to conduct triage. In this time, the only patient ID is input in the database.
After finishing triage, the clerk brings the first piece of triage tag (copy the paper written patient's information by triage officer) to the data-input-desk. Then the staffs at the data-input-desk enters the patient's information such as the name, date of birth, age, address, remarks by reading the copy paper in the present system.
On the other hand, the patient who finished the triage moves to the each treatment zone. When the patient arrives at the zone entrance, the FeliCa card is read by the FeliCa reader to record the location and the time automatically as the pass-processing. This is same way for the other zone or department where the PC for the present system is set.
Thus, even if there is a change of triage level, it is possible to conduct the same pass-processing at the new place. The new triage level can be updated in the present system automatically in this way.

4.3. Results

Figure 3 shows the time history of each patient's triage level, taking the patient in the vertical axis and time in the horizontal axis. The staff in medical institute and the government can understand the triage level of all patients from the time when the patients are received in hospital to discharge from the hospital by following time history. The change of triage level also can be understood in this figure.
The forward-command-headquarters directing the assignment of medical staff could take a proper action to manage the triage work based on understanding the situation such as the number of current accepted patients in the hospital, the number in the different triage level at each treatment zone in real time provided by the present system.
The family of patient visits to the hospital, which can be considered as that the family stays to look for patient status and location. However, immediate response is difficult for the hospital in a situation of a huge number of patients. Because they cannot search the patient, for whom the family is looking for in the paper-based patient's information. By using the key-word search function in the present system in this drill, the all staff in hospital can search immediately the patient they are looking for.
Figure 4 shows the time history of the number of patients in each triage level. The number of patient in the Green zone has increased just after the triage drill starts, 50 patients stay there at 10:12, then, showing the tendency to decrease until 10:17. After that, the number of patients in green zone reached the maximum at 10:24. The first patient in red zone was accepted at 9:43, 5 patients were received treatment at 9:53. The first patient in black zone was accepted at 10:03, 3 patients were received at 10:21. Similarly, **Figure 5** shows the time history of the number of patients in each treatment zone. Neuroradiology department received the 9 patients at 10:09. Pharmaceutical department received 2 patients at 10:03, and not seeing the any remarkable concentration. Inspection department also did not show the remarkable concentration of patients, receiving 1 patient at 9:54.

Figure 2. PC and FeliCa reader set at Department of Radiology.

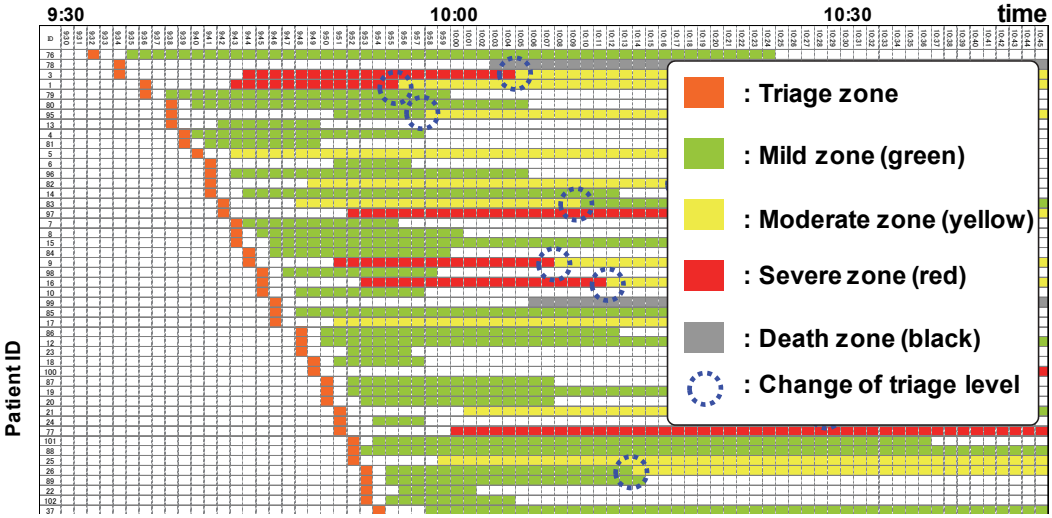

Figure 3. Time history of patient triage level

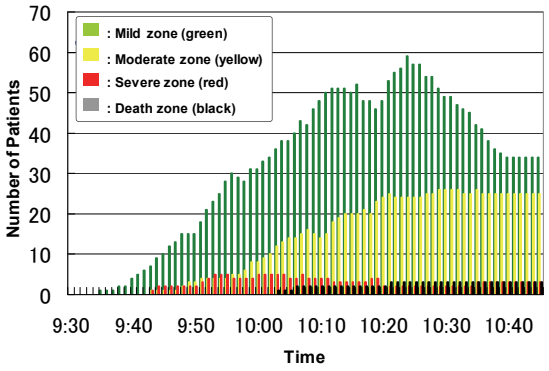

Figure 4. Time history of the number of triage level

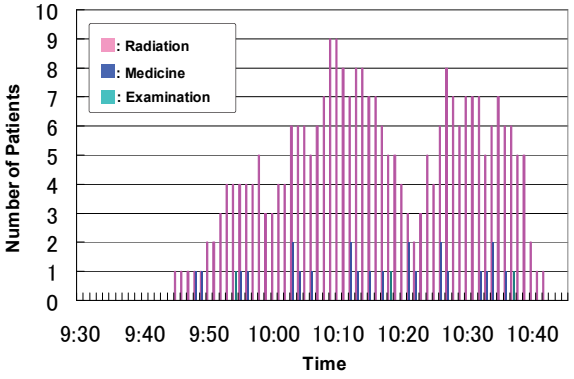

Figure 5. Time history of treatment department

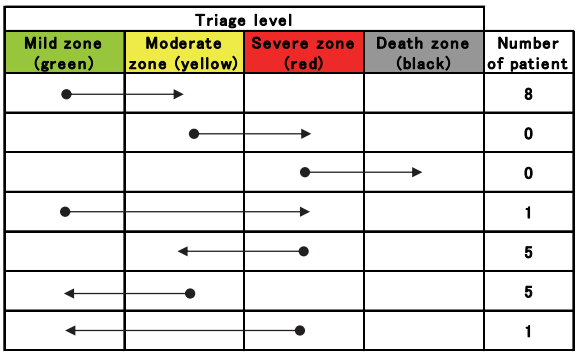

Figure 6. Pattern of triage level change

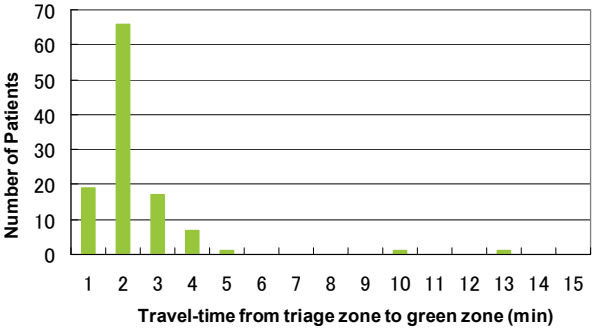

Figure 7. The lead-time from triage zone to green zone

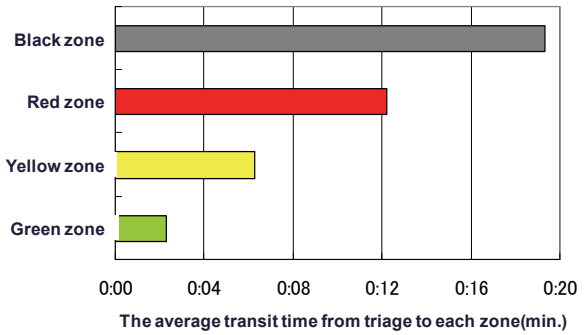

Figure 8. Average lead-time from triage zone to each zone

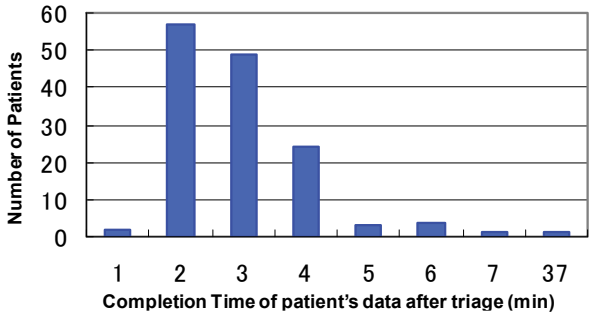

Figure 9. Time until complete the patient data at input desk

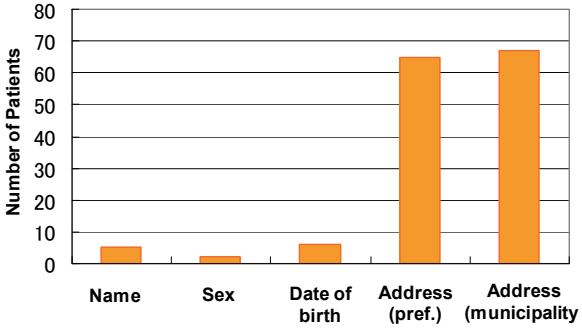

Figure 10. Number of un-entered item of personal information

a) Judge for assignment of medical staff b) Patient's number by Bar-chart

Figure 11. The forward headquarter

Response to the Changes of triage level: Totally, there is the change of triage level for 20 patients (**Figure 6**). The change from the green to yellow was 8 patients, 1 patient from green to red, 5 patients from red to yellow, 5 patients from yellow to green, 1 patient from red to green. In this drill, because of over-triage was conscious, the change of triage level was affected by the over-triage.
Transport after triage: It is possible to start treatment early, if we can reduce the lead-time from the triage zone in the front of hospital building to the each treatment. In particular, it is necessary to transport as soon as possible for the patients to be mild who is the majority to the all patients and not to make dwell time at triage zone in front of hospital building. **Figure 7** shows the lead-time from triage zone to the green zone for the 112 patients who were judged to be mild. 19 patients arrived at the green zone by taking 1 minute after triage, in the same way, 66 patients by 2 minutes, 17 patients by 3 minutes, and the average leading-time was 2 minutes and 18 seconds. This data can be understood that the support member respond quickly to transfer the patients. **Figure 8** shows the average travel time from triage zone to each treatment zone. The green zone shows the shortest time, 2 minutes and 18 seconds as described above. And also, the travel time from triage zone to yellow zone shows the average of 6 minutes and 18 seconds (20 patients), to red zone shows the average 12 minutes and 13 seconds (9 patients) and to the black zone shows the average 19 minutes 20 seconds (3 patients) respectively. The yellow and red zone shows the longer moving time. This is because that these zones locate far from triage zone compared to the green and black zone, and there are many patients transferred by using a stretcher or wheelchair due to the heavily injured.
Input of personal information: The time take from the triage to the complete of the personal data input such as name, day of birth etc. was average 3 minutes, minimum 1 minute and maximum 37 minutes (**Figure 9**). The patient with the longest time of 37 minutes was deceased (black zone), it takes time to identify the individual. There is record that shows the personal features like "blonde hair, blue shirt, confirm of the dead at 9:34" in remarks. And also, from the time history, triage at 9:34, the dead is confirmed 9 minutes after that, transferred to the black zone, and then the personal data is entered. As for the accuracy of the input item, there are 5 patients is with no input of name, 2 patients with no input of gender, 6 patients without date of birth data, 65 patients without address.(**Figure 10**). The 3 patients out of 5 patients without input of name are recorded showing with their feature like wearing black clothes as for personally identifiable information in the remarks.
Assignment of medical staff: The forward-command-headquarters directing the assignment of medical staff could take a proper action to manage the triage work based on understanding the situation such as the number of current accepted patients in the hospital, the number in the different triage level at each treatment zone in real time provided by the present system (**Figure 11**).
Family support: The family of patient visits to the hospital, which can be considered as that the family stays to look for patient status and location. However, immediate response is difficult for the hospital in a situation of a huge number of patients. Because they cannot search the patient, for whom the family is looking for in the paper-based patient's information. By using the key-word search function in the present system in this drill, the all staff in hospital can search immediately the patient they are looking for.

5. CONCLUSION

This research developed an IT triage system for collecting disaster medical information in real time and sharing it among related institution in entire area. Felicia card and card-reader are used to constitute of this system to obtain the number and condition of patients etc. in real time.
A disaster drill was held at the Yamanashi University Hospital with 450 participants. TRACY was examined its availability and practicability by using in this drill. From the result of that, the present system can obtain the number of patients for each triage level and the accepted number of patients in each diagnosis and treatment department in real time, including response for changing triage level and the people looking for their family in hospital. In the point of the information sharing in the entire area, the patient's information can be shared among hospitals, the administration, and residents in real time.
The feedback and opinions were widely obtained from the entire evaluation meeting and the meeting with the mainly triage officer held after the triage drill.
From the results, the present system can solve the traditional problem such as the hospital cannot make

a plan to receive the patients, the hospital cannot immediately answer the location and triage level of the patient to their families who are looking for details and it is impossible to take a proper action to manage the staff assignment for the forward-command-headquarters.
In addition, information on the degree of concentration of patients at each hospital can be shared between medical agencies and the governments in real time through the database. Therefore the patient transportation can be conducted by avoiding to the hospital which is busy or over capacity, and effective transportation is able to be achieved in the entire region. Although the patient concentration information is required high real-time data-collection, this system can work even if a large number of patients in the case of large-scale disaster.
Therefore, this system has the availability and practicability to the triage in the disaster.
On the other hand, we also discuss the issues and needs in the future.
(1) How we can consider the patients without reading the FeliCa card in the confusion/busy of hospital and the patient whose arm cannot move due to injury. We discuss the mobile type FeliCa reader is available to those patients.
(2) It is better to show the bar-chart and patient list at each zone or department to understand/share the latest status of entire hospital.
(3) The pass-processing can be additional work for the patients and staff. However, as this system can provide the status of hospital and share the data in entire region, the related people can take a better action.
(4) How we can set up the system as soon as possible after the disaster occurs. The present system can install to the PC which are used in the daily hospital working. This system is developed as the Web application, the client PC is not required installation in advance, and also, the present system can be used in a PC machine-independent. Therefore, the system can work by connecting only FeliCa reader to its PC.
These discussions are implementing to increase more practical level in the next drill. We will expand and examine TRACY according to the result obtained this triage drill.

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