Construct an IT-based Integrative Emergency Medical Service Model

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Abstract*-This research is to construct a geographically redundant emergency medical service system by using wireless PDA (personal data assistant) with proper user-interface, the optimum routing software and integrated database management system. XML-native database management is recommended to link to hospitals, other command centers and traffic databases so that the database of medical care capacity of hospitals can be dynamically updated and shared. GIS (geographical information system) and route optimization algorithms are integrated so that the best routing and assigned hospital information can be sent to the EMT (emergency medical technician) in the field when pre-hospital care data form is received from him. By using a GPS-enabled (global positioning system) PDA, the EMT can finish pre-hospital care data form by checking the pre-formatted items easily and send it back via public wireless network such as 3G, GPRS or WiMax, etc. to the center quickly. It can improve the efficiency of the emergency medical care system greatly and force the EMT (emergency medical technician) to file the pre-hospital data on-line. With this information, the hospital can have more time to prepare the resources before the injury arrives. With built-in camera, the EMT can take the pictures of the patient and the scene, and send them back to command center to enhance the functions of pre-hospital care data.*

Some information is necessary in order to properly construct the system. The needed information includes items of pre-hospital care data form and its display format or the human-machine interface for the PDA, items of medical resources needed for emergency care to be stored in the database, the criterion of optimum algorithm, the criterion of integrative database, the criterion of geography redundancy, and the process of the operations. To collect these six kinds of information, focus group method and in-depth interview are recommended to achieve it.

Keywords*:* Emergency medical care and rescue law, Rescue and care command center, Pr-hospital care data form, XML-native database management, PDA

1. Introduction

Since the “Emergency medical care and rescue law” was passed in August of 1995 in Taiwan, there have been four revisions. The most recent revision was in June of 2007, which came into force on July, 11, 2007. It reflects that the government highly endeavors to meet people’s need and maintain social justice. The new revisions of the law classify the ranks of the responsible hospitals in emergency medical care. The EMTs’ capability to classify the injuries and patients, and send them to the right hospitals will be enhanced. The responsible hospitals will have to help EMT via communication system judging the situation at the scene and ensure the quality of the emergency medical care. Therefore, to establish an efficient, effective and reliable pre-hospital medical care communication and IT system is extremely important.

However, there still exist in reality some problems of emergency medical care and rescue operations such as not being able to file pre-hospital care data in real time, and difficulties of updating dynamically the database of

emergency medical resources and capacities information. The problems make the emergency care system ineffective and thus bring un-satisfactions to the patients and their families. Therefore, it is urgently needed to plan a flexible and reliable emergency care system without the above problems. To accomplish such goal, to construct an integrative emergency medical system by fully utilizing the ICT (information and communication technologies) is the only solution.

By not being able to file the pre-hospital data in time and comprehensively, if there are some medical disputes happen afterwards, it provides the patients' family good excuses that EMTs had not done their duties and thus claim via lawsuit for big compensations. To protect the EMT from unpredictable loss, it is mandatory to provide EMTs effective means that they are able to fill up the pre-hospital data form efficiently in the adverse and emergency context at the scene and send it back online to the command center as the evidence before going to hospital. Based on the data, the hospital can prepare the necessary resources in time needed to rescue the patients or injuries.

2. Literature Review

Tsai et al. [6] find the implementation of pre-hospital care in Taiwan is still in its infancy. The Department of Health has organized pre-hospital care under a medical networking infrastructure island-wide since 1988. The work force is mainly drawn from fire-fighters who are now acting as first line emergency responders to 119 calls in most of the regions. Achieving coordination among the medical facilities, public health agency and public safety agency is a challenging and difficulty task. They conduct a retrospective census to assess the level of public satisfaction with the emergency medical services provided in Tainan region. Ninety percent of emergency calls have a response time of 8 minutes or less. Five eighths of emergency calls are trauma related. Sixty-five percent of the 119 users state that it is the first time they use the service. Over 90 percent of the respondents are satisfied with the services provided by the 119 personnel, but only 26.3% are pleased with the care they have received in the emergency room. The study reveals that the general public demands not only rapid transport from the scene but good service during transport as well ($p=0.0027$). The most common reason given for satisfaction with the 119 service is the compassionate attitude by the pre-hospital care providers. In contrast, the public feel the medical professionals in the emergency department display apathy towards their problems.

Yeh et al. [9] analyze the pre-hospital care records from hospitals with emergency facilities in Taipei collected between December 1998 and January 1999. In total, 927 pre-hospital care records are collated and the quality of emergency care documented by these records evaluated. The general data for ambulance care patients are recorded almost intact. Vital signs are not initially recorded in 22.0% to 30.1% of cases, and records of the second set of vital sign observations are less reliable again, only in 50.4% to 54.1% of cases. This suggests that there is room for improvement in pre-hospital care documentation. In 29% of cases, oxygen was not delivered at sufficient rates. Cardiopulmonary resuscitation following out-of-hospital cardiac arrest was not performed in 63.2% of cases, in all likelihood increasing patient mortality. These results highlight the need for improved standards of pre-hospital care documentation in Taiwan, which should help to improve patient management in emergency medical care facilities.

Chi et al. [4] evaluate disaster assessment information communication in Taiwan to determine the factors that affect performance of the communication system. A survey is done to the firefighters who attended on emergency medical dispatch training course. 61 respondents complete the questionnaires. 67% of respondents feel that the current communication of situation assessment information is bad, while 33%

considered it fair, good, or excellent. 48% feel that there should be an inter-organizational, local emergency medical service system responsible for the coordination, and quality control. They conclude that there are plenty of room to be improved in the communication processes and quality on the emergency medical care communication system. Chi and Liaw [3] do another survey to 50 EMTs in Taiwan and find that the response time is considered as the most critical factor to be improved in the emergency medical service system.

Chang et al. [2] claims that the support systems for the Emergency Medical Services (EMS) at mass gatherings, such as the local marathon or large international baseball games, are underdeveloped. They extend well-developed, triage-based, EMS Personal Digital Assistant (PDA) support systems to cover pre-hospital emergency medical services and onsite evaluation forms for the mass gatherings, and to evaluate users' perceived ease of use and usefulness of the systems in terms of Davis' Technology Acceptance Model (TAM). The systems are developed based on an established intelligent triage PDA support system and two forms. The two forms are the general EMS form from the Taipei EMT and the customer-made Mass Gathering Medical form used by a medical center. Twenty-three nurses and six physicians in the medical center, who have served at mass gatherings, are invited to examine the new systems and answer the TAM questionnaire. The PDA systems are composed of 450 information items within 42 screens in 6 categories. The results support the potential for using triage-based PDA systems at mass gatherings.

3. Construction of the IT-based Integrative Emergency Medical Service System (IEMSS)

General

As described in the literature review, Tsai et al.'s [6] study reveals that the general public demands not only rapid transport from the scene but good service during transport as well ($p=0.0027$). Yeh et al. [9] find that vital signs are not initially recorded in 22.0% to 30.1% of cases, and records of the second set of vital sign observations are less reliable again, only in 50.4% to 54.1% of cases. they suggests that the pre-hospital care record documenting needs to be improved. Chi et al. [4] finds that the processes and quality on the emergency medical care communication system need to be improved. Chi and Liaw [3] argue that the response time is the most critical indicator in the operations of the emergency medical care system. Chang et al. [2] claim that the support systems for the Emergency Medical Services (EMS) at mass gatherings are underdeveloped. The potential for using triage-based PDA systems at mass gatherings is supported.

To address the above key points of the previous researches, this study attempts to construct an IT-based Integrative Emergency Medical Service System (IEMSS) with the key components such as PDA, the software package of the most optimized route, integrated database management system, and geographically redundant data centers. It will enable EMT to finish easily the pre-hospital record in the emergent and panic environment by simply checking on the pre-formatted built-in forms in PDA in few minutes. The filled forms can then be sent back to the command center online in real-time to ensure the correctness and timeliness. The host computer in the command center will then recommend the proper hospital with the needed resources and the best route to arrive at the hospital. The processes force the EMT to send back the filled pre-hospital record in order to get the recommended hospital. Otherwise, he will not be able to know the destination to go. By doing so, the problems of pre-hospital record filling in real-time can be solved. In addition to solving the above problem, we also need to solve another problem that the current database of emergency medical system cannot be dynamically updated.

To solve the both problems at the same time, this study suggest the use of the new hi-tech products such as: (1) the wireless PDA with GPS and camera that is to be used by EMT; (2) the routing optimization software; (3) Native XML

DBMS [6][7] integrated with GIS (geographical information system); (4) Mobile computing data processing mode; (5) the geographically redundant database with the necessary computer hardware. With the new software and hardware in the system, the operational processes of EMT and the operators in the command center would also be changed.

The main new processes will include:

(1) For EMT, the filling of the pre-hospital record form will be done by checking item by item on the pre-formatted form embedded in PDA to replace the old manually filled form. The form will have to be transmitted to the command center in order to obtain the recommended hospital and the best way to go there. The transmitted form will also be time-stamped and used as the evidence in case of future disputes. It also enables the hospital to prepare the needed resources to rescue the injuries and patients more effectively. To enhance the filled form, EMT can use the camera on the PDA to take the pictures at the scene to let the doctor guide the EMT to provide the in-time proper first-aid to the injury and patient.

(2) After receiving the pre-hospital form and the location information sent back from EMT, the computer at the command center will allocate the first and the second priority hospitals that have the needed resources to provide the help from the dynamically updated database and recommend them to EMT via wireless system (e.g. 3G, GPRS, WiMax). Meantime, the computer will also recommend the best routes with the least traffic and the shortest distance to go to the hospital to save the most precious time. The GIS map on the PDA can show the routes.

(3) The Native XML DBMS in the computer of the command center would continuously receive the most updated data of medical care resources and capacities of the other hospitals and updated its database. Together with GIS, routing optimization software and mobile computing software, the computer of the command center will always be ready to send the recommendation of the best routes to EMT after receiving continuously the updated external traffic information.

System Architecture

Figure 1 is the architecture diagram of Integrative Emergency Medical Service System (IEMSS). It is the diagram for one command center. In one region, there are many command centers that can be linked together via leased line or internet to form a regional network. In a country, the regions can be linked together similarly to form a national emergency medical care network. The data can then be shared and dynamically updated.

Directly administrated by this command center, there are “n” EMTs. One EMT carries one PDA. The operation of PDA has been explained above. The main parts of the command center and the functions are explained below:

Database Management System (DBMS)

In the command center, there is an IEMSS server which is the main host computer. The server is equipped with the Native XML DBMS. To the other command center

The DBMS classifies the database into GIS Database, Traffic Database, Medical Resources & Capacity Database, Patients/Injuries-Resources Requirement Database, Pre-hospital Records Database, Special Medication Database, and Emergency Care Process Database. GIS Database manages the data of road maps. Traffic Database manages dynamically the external traffic information received from outside source. Medical Resources & Capacity database manages the available doctors, medicines, bloods, beds, etc. of the hospitals fed in from the outside hospitals. These data change continuously. Therefore, the data have to be updated dynamically. Patient/Injury-Resources Requirement Database manages the data of different requirements to handle the different kind of wounds and diseases. The requirements can be sent to EMT as a guide of providing the first-aid. Pre-hospital Record

Database manages the data of forms and pictures sent back by EMT. Special Medication Database manages the data of rare diseases, and rare blood-type owner list, etc. Emergency Process Database manages the data of the processes of all the possible scenarios.

Native XML DBMS provides the server the most efficient ways to control the access and storage and to link the classified databases via network. It integrates the GIS system, optimization system and uses the mobile computing data processing mode to provide the EMT the recommendation of the best route. It does the same for the hospital recommendation.

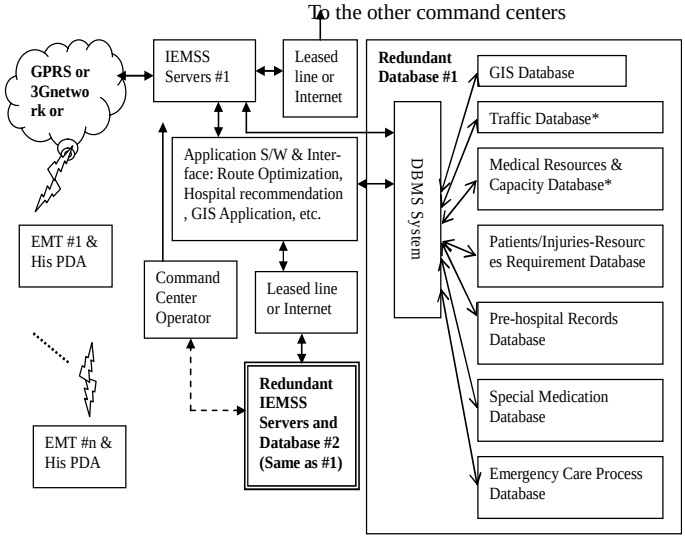

Figure 1. IEMSS Architecture

Application Software

The main application software includes GIS system, Route Optimization system (ROS), Hospital Recommendation system (HRS), and Redundancy system. They are installed on the server. When the server receives the GPS location information and the pre-hospital record data from EMT's PDA via wireless network, HRS goes to the Medical Resource and Capacity database to find 2 to 3 the most suitable hospitals that have the needed resources and capacities to handle the problem. Then it give the results to ROS to go to GIS and Traffic databases to compute the most optimized routes from the EMT location to the recommended hospitals. The server transmits the resulted first priority and second priority hospitals and their routes information to EMT and the operator of the command center. The EMT selects one hospital and sends back the selection to the operator of the command center. The operator then sends the pre-hospital record to the selected hospital, gets confirmation from hospital and sends confirmation to EMT to send the injury or patient to the confirmed hospital.

During the transition to hospital, the hospital can start to prepare the necessary resources based on the received pre-hospital record. If the local IEMSS cannot find the suitable hospital in the assigned area, then the operator will link to the other IEMSS in the region to find the suitable hospital. If the suitable hospital still cannot be found in the region, then the operator on the regional command center goes to the national IEMSS to find the suitable hospital in the other regions.

Due to that IEMSS relates to human's life and death, it must provide reliable and non-stop operations for both hardware and software systems. The geographical redundancy fits such requirements. The redundant system includes completely the same hardware and software systems with the main system, but at the different physical location that is e.g. 50 KM away. Normally, only the main system operates and the data between the two sides synchronized to each other. If the main system failed, the redundant one will sense it and take over the operation automatically. The operator of the command center can operate and control the redundant system remotely. The EMTs outside would not feel any difference when the redundant system is in operation.

4. IEMSS Implementation

To collect the needed information to implement the new IEMSS is a kind of exploratory research method. It deals with the domain knowledge of emergency medical care, computer science and communication networking. To achieve it, the "focus group" and "in-depth

interview" will be the proper approaches [1][5]. The in-depth interview can be done as the supplementary means to the focus groups. For more specialized technical knowledge in medical and IT, it can be done to the specialists. The content analysis of the interview results is the same as mentioned for the focus group.

The outcome of the content analysis will be summarized as: (1) The contents and the display form of the pre-hospital record; (2) The classified items of database; (3) The function requirements of the optimization software; (4) The contents requirements of IEMSS; (5) The function requirements of geographical redundancy; (6) The entire pre-hospital processes. Based on these outcomes, the specifications of the IEMSS subsystems can be drafted. The needed equipment and software can then be purchased according to the specifications.

5. Conclusion

This paper conceptually constructs an integrative emergency medical service system (IEMSS) that includes the use of hi-tech IT products, computer software and the new processes. The new system will improve the efficiency and effectiveness of the emergency medical service to the public and thus obtain the high satisfactions from the public, not only from the injuries and patients themselves, but also from the families, friends, and relatives of them. It deals human's life or death. The influences are broad and profound. Therefore, it not only concerns with publics' benefits but also government image. The implement of the IEMSS is worthwhile to consider.

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