3G

Japanese Telemedical Concept of Ambulatory Application
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Abstract Transmission of in-ambulance data without inconveniencing or undue effort by the rescue crew—in other words, automation of in-ambulance activities (measurement/analysis, activity recording, message transmission)—is essential in implementing uniform medical control standards across the nation. However, the 3G mobile phone has propagation problems at urban area and severe congestions after major disaster to support mobile telemedicine. So we are expecting the Quasi-zenith satellite with nationwide coverage. In near future, we are expecting the data transmission of image of pharyngoscopy, motion picture of light reflex, 12-leads ECG, automated ultrasonic echo and vital signs from ambulances to triage center. For example, Thrombolytic agents are reportedly effective even when injected into a vein, if injected in the early stages of acute myocardial infarction, that will reduce medical costs, resulting in high-quality services available uniformly across the nation. This paper describes our basic concept to support ambulatory application.

Keywords Communication technology · Pharyngoscope · Electrocardiogram · Light reflex

Objectives Transmission of in-ambulance data without inconveniencing or undue effort on the part of the rescue crew—in other words, automation of in-ambulance activities (measurement/analysis, activity recording, message transmission)—is essential in implementing uniform medical control standards across the nation. One of key elements for this automation is communications technology (CT). Its development is a must for emergency transportation for the near-future. Currently, no country has succeeded in supporting patients through CT on board ambulances. As an ER doctor, I believe the need to do so will grow in the near future. This paper describes our basic concept of CT to support ambulatory application.

Technical communication background

What is CT?

In Japan, ECG monitor, peripheral saturation of blood oxygen, cardiac defibrillator, and other ME equipments have been already installed in 4,800 ambulances. The purpose of in-ambulance CT is to improve emergency rescue quality by transmitting patient data and ambulance GPS data to the triage center automatically, with no inconvenience to or undue effort by the crew. Ideally, CT would connect the patient monitor online with TCP/IP and record crew activities automatically and electronically. In reality, time standards for the ambulance clock, cardiograph, and communication devices are not synchronized in Japan, and rescue crews must match these manually every morning. Synchronizing these devices would be a simple matter if the devices were linked via TCP/IP connections.
The third generation (3G)-mobile phone

Some believe communications with moving ambulances should be based on the 3G mobile phone network [1–4]. Is this correct? Is the 3G mobile phone network good enough to ensure multi-path high-speed transmission from fast-moving ambulances? The answer is no, even in Japan, where a 3G network is established nationwide.

Multi-path communication This technology is not yet established. If the base station antenna is located very close to the mobile terminal and communication occurs in line-of-sight mode (Nakagami–Rice fading), communications will be reliable and stable and throughput close to nominal values. But in non-line-of-sight mode (Rayleigh fading), communication is not reliable under multi-path conditions, resulting in inadequate throughput. Maintaining a 384 kbps connection rate (the FOMA uplink standard) during transmission from a moving car is quite difficult. None of the various studies involving transmissions from ambulances using the 3G network have led to introduction of a practical system.

Service area problems The number of base stations for the NTT DoCoMo 3G FOMA Service is now at around 3,200 in the Kanto-Koshinetsu area and 10,700 across the nation, with service areas expanding. The population coverage is about 98% nationwide as of the end of December 2007. This coverage, however, counts all city/village citizens when their local administration office exists in a service area. Undoubtedly, this approach counts mountainous areas and remote islands that are actually located outside service areas. Since mobile phone carriers follow profit-oriented market dynamics with the cream-skimming policy (sheding unprofitable areas), they will not invest money to construct base stations in these areas. Even with the advent of the 4G network, they will likely focus on urban areas while shortchanging rural populations.

Public wireless LANs

Are public wireless LANs useful? Wireless LANs are already in service at railway stations, airports, and main streets. If this system is deployed everywhere, broadband communications will be possible for public rescue vehicles such as patrol cars and ambulances. In an experiment, a Gifu (Japan) national road was equipped with a wireless LAN (Route-make terminals) by the Takayama National Road Office of the Land and Transportation Ministry. Since this assumes line-of-sight communications, transponders connected to NTT networks must be placed at every 0.5 to 1.0 km. Adopting this system for roads across the nation would involve exorbitant cost and infrastructure demands.

Geostationary satellites

“Geostationary satellite” is the term for a communication/broadcasting satellite that remains at a certain orbital altitude above a specific point on the Earth at all times. They orbit in synchronization with the surface of the Earth at approximately 36,000 km above the equator. They are called geostationary because they appear fixed in the sky when viewed from the ground. One geostationary satellite can cover the whole nation. However, there are two technological issues posed by the limited transmission power of the ambulance and antenna gain when sending data at a high speed from a moving mobile terminal.

1. Blocking by buildings (communication interruptions)
2. Gain-to-noise temperature ratio (G/T) of the satellite receiver antenna

Problem 1 occurs because Japan is located at mid-latitude, not at the equator. G/T in 2) expresses sensitivity on the satellite side—a ratio of front gain G to overall noise temperature T on the receiver side. A common way to increase gain is to use higher frequencies and increase area antennas with fine mirrored surfaces.

Quasi-zenith satellite (HEOs)

As required by Kepler’s second law, sweeps across equal areas of an ellipse take the same amount of time. If there are three satellites and each of them appears over Japan at zenith every 8 h, this is the same as one satellite being present 24 h. Such systems have already entered practical use in Russia and the USA. These satellites can avoid propagation blockings caused by buildings and can be used efficiently when combined with a geostationary satellite that provides another line-of-sight propagation (directional diversity). The successful development of a large expandable antenna of spacecraft also makes this system more feasible. This system is now expected to be used for disaster prevention and emergency rescue [5]. Japan will launch GP-use quasi-zenith satellites incorporating Ku-band transponders in 2012.

Current status of the public phone network (immediately after a disaster)

Immediately after a disaster, the number of calls placed over the public phone network increases sharply (Fig. 1). The resulting congestion can make connections highly unreliable. For example, immediately after the Niigata earthquake, as shown in the figure, the number of calls increased by a factor of 50 [6]. The Erlang-base call loss ratio (connection failure probability) rises to 0.99 or above. This means that even 100 calls will fail to ensure a single
successful connection. In short, public networks are of limited use during times of disaster. A disaster/emergency rescue-dedicated network is needed, independent of the public network and capable of nationwide coverage [7].

Universal service fund

Carriers competing in the free market are free to shed services for emergency rescue, for the disadvantaged, and for people living in remote areas. A universal service fund which is possible in stable economies, aids in such situations. The International Telecommunication Union (ITU) recommends the deployment of this system in many countries, based on a WSIS (World Summit on the Information Society) action plan for resolving digital-divide issues.

In Japan, an extra charge of 7.35 yen/month has been imposed on each call across the board since March 2007. This fee is used to support services in high-cost remote areas in Japan; in other developed countries, a similar fee is used to fund communication applications related to medical care and education. In the USA, $50 million was paid out in 2007 for medical services for telemedicine to help those living in remote areas.

A 100% cash back or tax relief measure should be considered as part of a universal service policy to support wireless and satellite networks for emergency rescue-dedicated purposes.

CT assisted treatment technology

Emergency rescue activity record

Electronization is the key for quickly creating accurate activity records. Providing accurate information to the destination hospital is crucial, as is transmitting data back to a PC at the station automatically to minimize inconvenience. For this purpose, a system of handy PDA-like terminals must be provided to rescue crews, and a gateway system deployed to send PDA data to the network from the ambulance.

Voice recognition (particularly dispersion-type voice recognition) to eliminate the inconvenience of character input for busy rescue crews represents a challenge in innovation that Japan, as a leader in the development and international standardization, should be fully equal to. Other electronic tools will be needed to assist rescue crews improve their skills in providing medical treatment in an ambulance, as well as searching for hospitals. Additionally, electronic support is an essential element of a safe first-aid system capable of reliably identifying serious hidden symptoms.

Medical control via communications circuit

In Japan, the medical treatment of patients in the ambulance poses difficult issues because it falls under the purview of two different ministries—the Ministry of Public Management, Home Affairs, Posts and Telecommunications and the Ministry of Health, Labor and Welfare. Medical control based on a Notification by the Fire-Defense Agency Emergency Rescue Manager involves (1) early instructions to the rescue crew; (2) doctor’s post-verification of the treatment provided; and (3) continuing education and training of rescue crew.

The restrictions imposed by Article 20 (which requires a face-to-face diagnosis) under Medical Law can be lifted when a reliable communication network is used, according to Notification No. 1075 of the Health Policy Bureau, Ministry of Health, Labour and Welfare, issued December 24, 1997. A revised Notification further permits so-called telemedicine via networks for patients in ambulances.
In short, Japanese law permits medical control of rescue crews (for basic treatment and care) and higher-level treatment by the triage doctor located at the triage center. However, a high-quality communication path is the minimal condition necessary.

Specific diseases

Successful treatment of coronary clogging is known to be highly likely if an acute heart attack patient receives medical treatment in the ambulance and a thrombolytic agent is administered within 60 min of identification of a vein route by the rescue crew. This treatment, however, may cause bleeding in the skull, making it necessary to monitor blood pressure constantly. An echocardiogram and a 12-lead electrocardiogram are essential for correct diagnosis of a heart attack, whereas the position of certain clots is easily detected by heart auscultation based on independent element analysis. This technology has been considered in certain countries where the patient must remain for relatively long periods in an ambulance, and related papers have been published by IEEE and APT [2, 8, 9].

The CT-based medical control will be effective with various patients suffering from cardiac or respiratory arrest and external injuries, as well as acute heart attacks. While not a magic bullet, this technology will enter actual use in the near future. CT offers high potential for improving diagnoses and eventually reducing medical costs [10–12] (Fig. 2).

Networking in-ambulance devices

At present, the measurement devices in ambulances are not connected to any networks. They are not even synchronized automatically. At present, the best solution appears to be to network them and to transmit data via a TCP/IP intranet on board the ambulance. Listed below are the parameters that must be monitored.

(a) Macintosh with integrated type of CCD camera (pharyngoscope)

With the hard type of the pharyngoscope, we can extend a larynx and observe the whole larynx under the line of sight. With the integrated type of the small CCD (charge coupled device) camera, we can monitor and record the process electronically, and transmits image data via telecommunication circuit. Especially, it supports a procedure of an endotracheal tube insertion and/or removal of a foreign body in trachea. Without this monitor, a 20% of patients will be misplaced tube and will become severe hypoxia during transportation.

(b) Light reflex image (pupillometer)

Conventional methods of analog papillary light reflex examination performed inside emergency vehicles tend to be associated with significant amounts of error that impede precise quantification of changes in pupil size. To establish a simple method for quantifying nervous function in prehospital care, we applied a technique for processing video images captured by a CCD camera to enable accurate measurements of the rate of change in pupil size. While this method can be used to assess either direct or consensual light reflexes, we focused in this study on an ipsilateral (direct light) reflex pupillometer, since this choice raises technically more challenging issues and is expected to result in significantly smaller design [13]. Based on this image, it should be possible to diagnose not just brainstem problems, but dementia and peripheral nerve disorders. The shrinkage speed of the pupil declines in Alzheimer disease and the diabetes.

(c) Twelve-lead electrocardiogram

The three-lead ECG that we all use with our monitors on a regular basis can only detect an arrhythmia. Because the three leads placed in the anterior thoracic monitor myocardial electric activities with hexaxial view. While the 12 lead ECG shows not only hexaxual view, but also the cross section view, for example in a transverse horizontal plane with V1-6. So we can make a diagnosis of acute myocardial infarction with reciprocal changes of ST elevations.

Europe is the leader in this field, while in Japan Yokohama City has just introduced the technology. It provides information on ischemic heart disease during transportation and enables early aid for improved prognosis and reduced medical cost. This should prove useful if it can be automated and network connections made easier.

(d) Automated ultrasonic measurements

A serious blunt thoracic injury have to be treated within 60 min after an accident. There is a strong possibility of heart injury and/or of great-vessel-injury that shown fluid collection in a thoracic cavity. In the same way, the abdominal blunt trauma has a risk of hepatic injury and/or injury of inferior vena cava. So EMTs have to rule out the fluid collection in the peritoneal cavity with ultrasonic tomography.

With robotic arm holding curved array scan probe, the US army continues to issue academic reports on automated measurement of heart wall movements for ischemic heart disease or trauma victim to check the absence/presence of thoracic fluid collection [14].

Discussion

Vision of medical controls for the near future

Emergency transport and medical care are intertwined. The extension of medical control is based on telemedicine and care by triage doctors located at medical control or triage.
centers. The ultimate goal is to improve prognoses and extend patient life expectancy. There is no question concerning the importance of prehospital care in reducing medical costs, which amount to 30 trillion yen annually in Japan [8].

Each prefecture currently operates a medical control center. However, assuming that the medical control center is only necessary for patients in serious condition (approximately 10%), one center should suffice for each Dou or Shu (state, six to ten in total). Another important goal is nationwide equality in such services. The former, or prefectural-based medical control center service aims to provide a service based on local conditions, while the latter, or Dou/Shu-based medical center service, places the priority on economy and equality. In either case, there will be no progress in medical control without the development of CT that can be effectively used in emergency transport.

Case of cardiac infarction

In Japan, heart attacks rank second as a cause of death; in FY2006, 172,875 died of heart attacks. Annually in Japan, 49,000 people experience acute cardiac infarction. According to nationwide statistics for emergency transport for FY2006, heart disease patients accounted for 9.3%, or 271,943, of all those transported. It appears that close to half the patients struck by acute cardiac infarction die within one hour. The causes of death are cardiac arrest due to Ventricular Tachycardia, Ventricular Flutter, and Ventricular Fibrillation. A significant number of patients may be saved if they receive proper treatment within one hour after the attack. The patients who are lucky enough to be transported to a CCU in emergency centers are in most cases given thrombolytic agents while undergoing PTC (Percutaneous Transluminal Coronary) operations to remove the coronary thrombus. Thrombolytic agents are reportedly effective even when injected into a vein, if injected in the early stages (within one hour after the attack). In fact, some trials of thrombolytic doses in ambulances have been initiated. However, it is known that all thrombolytics pose the possible risk of cerebral hemorrhage. For example, a thrombolytic thrombolys, now used in the emergency rescue center, resulted in cerebral hemorrhages among three patients, two of whom eventually died in Japan, although the number of such incidents was relatively low. Thus, the use of such thrombolytics without question requires continuous monitoring of blood pressure and blood pressure control by medical experts. In case of remote medical observation in the ambulance during transport, a patient struck by an acute cardiac infarction will be performed suitable triage by specialist at Triage Center with transmitting 12-lead ECG, and Echography. After suitable diagnosis by specialist, a shot of a thrombolytic agent PTCA should be administered into vein. Assuming that early-stage treatment is successfully performed by administering thrombolytic agent into the patient’s vein in the ambulance, we estimate a reduction in medical costs for the treatment of acute cardiac infarction, based on the following assumptions:

1. Ten percent of the 271,943 heart disease patients transported in emergencies have just been struck by acute cardiac infarction (equal to 41% of patients struck by acute cardiac infarction are transported to hospitals via ambulance).
2. It is possible to use telemedicine during emergency transport to isolate the cause of the problem as acute cardiac infarction, based on data provided by a 12-lead electrocardiogram and cardiac ultrasonic imaging.
3. If an ambulance technician administers a vein dose of a thrombolytic to the patient under the instruction of doctors, the rate of improvement appears to be around 60%.

4. A patient whose condition improves thanks to early intervention will return home after a 7-day hospital stay, while a patient for whom the intervention has no effect is hospitalized 21 days on average.

5. The medical cost per hospitalized patient per is US$1,200 per day.

Reduction in medical cost during 10-year implementation=US$ 2 Billion. This is the amount of reductions in medical costs made possible by pre-hospital care in the event of acute cardiac infarction, based on assumptions 1 to 5. If the calculation is expanded to include cost reductions in other acute diseases and injury, medical expenses can be expected to be reduced even more dramatically. One solution for curbing medical expenses in Japan, which is currently growing 5% annually, is improving pre-hospital care. Proper implementation of this project requires high-speed data channels, since these will enable doctors to see the conditions of the patient in an ambulance as if the patient were in the next room. The communications channel is one of most promising solutions.

Momentum for international standardization

ITU-T (International telecommunication Union, Division of Telecommunication) SG16 Q28 is currently boosting the standardization of telemedicine technologies. Tasks related to this standardization effort are currently underway in each member nation. Now is the time for member nations to propose PDA specifications for use by rescue crews and procedures for emergency rescue wireless communications [15, 16].

Conclusions

High automation (automation of measurement, recording, analysis and transmission) of ambulance-borne devices is the goal of CT. Emergency transportation for the near future is expected to enable data transmission from ambulances automatically, without inconvenience to rescue crews, resulting in high-quality services available uniformly across the nation.

As of May 2009, no country had succeeded in deploying a high quality communication path for mobile terminals, although this remains essential for the smooth implementation of medical controls.

We are certain medical controls will be much improved in the near future both in quality and content as CT integration proceeds, and that such CT will significantly improve patient prognoses.

References


