differences among individuals'. In a region with genetic similarities, in which a diversity of acquired lifestyle customs co-exist, would it not be possible therefore to gather significant data through cohort research in the region?

Progress in science bestows upon people the promise of limitless possibilities and the means to live longer. Humankind has devoted much time and effort in the fight against disease.

In the near future, the international community is likely to face an unjust situation in which some people with the same disease will be cured while others will suffer and die.

It is this grave reality that must be addressed.

The Asia Cancer Forum bases its activities on the Universal Declaration of Human Rights, which states that everyone has the right to share in scientific advancement and its benefits equally. In aiming to utilize scientific advancement to address the issue of what we can do to ensure that the challenges that have been faced by industrialized nations are not faced by developing nations, the Asia Cancer Forum is engaging in discussion on the challenge common to both industrialized and developing nations, namely the inclusion of cancer in the global health agenda.

## SESSION 1: INFORMATION FROM THE HUMAN BODY

H.A. (RCAST) opened the meeting by requesting comments from Andreas Ullrich (WHO) and David Hill (UICC). Andreas Ullrich noted that the WHO is working very hard to include cancer in the context of NCDs on the global health agenda. What needs to be done on a global scale is exactly what is happening in the Asia-Pacific region in fora like the Asia Cancer Forum, and these activities are very much in line with WHO strategies and policies. David Hill noted that the Asia Cancer Forum is a series of important discussions on the issue of cancer. He stated that the UICC is a global organization, but has a particular concern about cancer control in low- and middle-income countries, many of which are in Asia. There is enormous potential for cancer control, which is currently not being fully implemented. As a species, human beings are very wasteful of the benefits of discoveries. We are not very good at implementing the benefits of discoveries as rapidly, effectively and equitably as we should. Forums such as the Asia Cancer Forum, which focus not only on research and discovery, but more importantly focus on delivering the benefits of research and discovery to populations, are extremely important and are to be commended. The solutions to cancer control lie in people connecting with each other and with their communities to implement the benefits of knowledge that we already have, and that is exactly what the Asia Cancer Forum is doing here.

H.A. presented the concept for this Asia Cancer Forum. The previous APCC was held in Japan and resulted in the issuance of the Asian-Pacific Consensus Statement by working groups, which aims to improve cancer health science in the Asia-Pacific region. At this discussion last year, it was concluded that cancer must be on the global health agenda and the Asia-Pacific region is ready to work toward this goal. The issues being currently faced are a rapid increase in population in Asian countries, an aging society and increased longevity, together with increased speed in diagnosis. For example, the population of China has a different demographic to that of Japan, but it will gradually come to look like the demographic pyramid of Japan in the future. Expenditure is also rapidly increasing in Asia. Comparisons between the E7 and G7 countries show that medical expenditure is rapidly increasing in E7 countries. Japan has a track record of good healthcare and low spending in terms of GDP. The low spending in Japan has created a number of issues, particularly with regard to the quality of life for medical staff. In other words, Japan has faced a number of cancer issues ahead of other Asian countries and Japan could provide a source of reference for other countries that will face these issues in the future. The aim of the Asia Cancer Forum is to come up with good proposals.

N.K. noted that 'Genetic Solidarity and Altruism' is a powerful phrase that features in the 'Inside Information' documents of the Human Genetics Commission (HGC) of the UK. The progress of innovation means that the significance of holding information and data is changing greatly. What is most important, however, is to ensure that each and every person transforms their awareness about the importance of information in an innovative world.

The Asia Cancer Forum is a body that is committed to strategic analysis in the area of cancer research. The current objective of the Forum is to achieve the inclusion of cancer in the Millennium Development Goals (MDGs) of the United Nations. A long-term perspective must be taken that looks ahead to the issues that will face future generations. It is important to start to consider the design of a social system for collecting and storing the information and data we ourselves posses.

### Pathology Networking in Asia

H.S. (Hamamatsu University School of Medicine) noted that cancer diagnosis is based on histopathological pictures and human pathology and cancer diagnosis is a mature scientific field. Histopathological language is common to all oncologists and other cancer specialists and it is now possible technologically to present histopathological pictures. Data can be stored and uploaded on a virtual slide website for joint use. Using this website, scientists worldwide could input their own opinions. Archives stored in digital format can last for almost forever. The virtual slide website is easy to use and browsable. There are many folders on the website featuring histopathological archives, for educational and research purposes, as well as for quality control. Each hospital can send images to a central hospital for diagnosis and compare images among multiple hospitals. The quality of the pictures

is much higher than conventional cameras. With high-speed Internet, it is possible to scan images to high resolutions. For virtual slides, no microscope is necessary, only a high-resolution CCD camera. The problem at the moment we face concerns Internet speed. Eventually, with the dissemination of broadband, this system will be able to be further improved around the region. Scanners are installed in 300 institutions at the moment. Histopathological diagnosis can therefore be performed 24 h around the clock using the worldwide network. In order to expand the network further, it will be necessary to develop infrastructure, including high-speed broadband Internet.

### Urgent Demand to Establish Asian Network of Pediatric Bio-resource and Tumor Banks for Better Cure of the Sick Children

A.N. (Chiba Cancer Center) talked about the urgent demand to establish bio-resource and tumor banks in order to better cure sick children. The cure rate of pediatric cancer is very low in many countries in Asia. Epidemiology of childhood cancer in developing countries is largely unknown. It is not known what genetic and environmental factors affect pediatric cancers, in contrast to the knowledge available on adult cancer. It is important to establish a standardized therapeutic and diagnostic system, which would be helpful for the development of epidemiology of pediatric cancers. In 2008, at the meeting of the Advances in Neuroblastoma Research (ANR2008) held in Chiba, Japan, the Steering Committee and the Advisory Board Committee of the ANR Association decided to take an action to establish the international neuroblastoma tumor bank (INTB). The INTB task force includes the establishment of a standardized diagnostic and database system. Neuroblastoma is a very enigmatic tumor, with most being very aggressive. Prognosis is very poor, even now. In order to solve this problem, a staging system was proposed. In order to promote new translational research in the field of cancer, it is necessary to establish a tumor bank system. More than 90% of neuroblastoma tumors in Japan are being sent to Chiba University for analysis. Chiba Cancer Center engages in genomic analysis of these tumors. Efforts are being made to propagate our standardized system to other countries in Asia. All countries agreed to establish a tumor bank; however, the central tumor bank and molecular diagnosis systems are still immature in Asian countries.

### Why Do We Need Global Collaboration in Cancer Research? Establishing Cross-border Transfer of Research Materials and Information

T.M. (National Institute of Biomedical Innovation) introduced one example of networking and commented on why a network is required, particularly in the Asian context. NCI is working to develop a bio-bank system in the USA. This is a very important attempt to share information and materials among cancer researchers, although it is currently limited to within the USA. Best practices are also issued by the NCI, the first version being issued in 2007. Diagnosis and treatment is not the end of a process, it should be the start for the next generation of research. It is therefore important to achieve integrity between clinical practices and research activities. The NCI also focuses on biomarkers, with the aim of providing transcripts for future use. The common practice for conventional medical research requires a large number of medical researchers and specialists. Researchers tend not to see the bigger picture behind research and it is therefore important to provide transparency in large projects so that researchers can understand their place in the research context. The creation of an international network would therefore be very important. A greater degree of cross-border fluidity is required, working on the already good level of interaction between cancer specialists across borders.

## SESSION 2: INFORMATION AS IT SIGNALS

### Global Strategies for Genome and Cell-based Informatics: High-performance DNA Sequencing and Expression Analysis Open a New Area

J.M. (Osaka University) explained the need for an Asian network from the viewpoint of engineering. Fighting against cancer is not simple. Everyone in the pharmaceutical industry is now seeking how to control the pathways and molecular systems of cancer cells. We require huge knowledge in order to achieve this aim, as cancer molecules have an enormous number of variations. Four-dimensional data are required to identify cancer pathways. In our laboratory, we have 200TB of data processing capacity, in order to engage in DNA processing, which provides us with a great deal of data. In Okinawa, we have 10 GB sequencers. We know that medical research is already at a very high level, but R&D remains at a low level, as a part of total expenditure. We therefore have to have more information-based medical systems. We need a system that all stakeholders would be able and ready to use. We have been working on the creation of a network and would like to ask you to join us in our efforts.

### Tackling the 'Lifestyle-related Cancer' with Cutting-edge IT

M.A. (University of Tokyo) talked about how to build consensus and share information using IT. Aging society is a serious issue as people are susceptible to other diseases in addition to cancer. In general, the collection of information data is generally done from the bedside. The next-generation system would have to be an interactive system. Cutting-edge systems including bar-code systems and wireless devices would help to create and disseminate data. Another issue is how to gather verbal information using IT. Next-generation data entry systems will need to incorporate measures for gathering verbal information in data format. Cloud

computing could solve issues of data storage in the future, as the storage capacity using cloud computing is virtually limitless and would enable further collaboration, including data entries from patients' homes, etc. If cloud computing is to be used, it is essential that the systems are secure and trusted.

## DISCUSSION

H.A. (RCAST) noted that it is essential that all Asian countries share information, technology and knowledge. He invited comments from other participants.

X.H. (Chinese Anti-Cancer Association) noted that Asia needs a forum to focus on the problems facing Asia. Fifty percent of new cancer cases annually occur in Asia, and from the presentations made at the 21st UICC World Cancer Congress, it is known that 80% of new cases of cancer are from low- and middle-income countries, like China, India and Pakistan and other countries in Asia. The issues raised by the presenters are very important and require action. Although there is a lot of knowledge and consensus on most cancers, we still need further information and consultation on some forms of cancer, including pediatric cancers, leukemia and central nervous system cancers, for example. The possibilities for medical consultation through the Internet would be of benefit not only for Asia but for the world, and would facilitate diagnosis for patients and help to diagnose and identify the correct therapies for patients and save their lives. The issue of a tissue bank is also very important. Six years ago, with the support of the National Foundation for Cancer Research (NFCR) from the United States, a Joint Tissue Banking Facility was opened at the Tianjin Medical University Cancer Institute and Hospital in China. Right now there are about 40 000 specimens. An Asian network is essential and Japan is leading the way on this project.

H.S. (Hamamatsu University School of Medicine) noted that Chinese pathologists have many more cases than ordinary Japanese pathological institutions, maybe due to the numbers of people who have variations of tissues. The Internet is a very comfortable way of developing relationships and colleagues in China and Asia should be encouraged to continue to develop such consultation systems.

Joe Harford (NCI, USA) pointed out that through the practice of tele-pathology, it is possible to have samples read in the USA that were collected in Japan during the night and thereby operate around the clock. In contrast, it is instructive to look at the situation that was encountered with pathology services in Ghana. When the Breast Health Global Initiative visited Ghana, the breast pathology reports were taking 6 months to complete, from the time the samples were collected, until the pathology report was submitted. The idea of getting a report in 18–24 h is very different from waiting for 6 months. Tele-pathology does have a great deal of potential for assisting low- and middle-income countries, where there are few pathologists. It is therefore incumbent on the USA and the Asian region to be thinking about how these technologies can be used to assist the low- and middle-income countries where there are no or few pathologists. This could be in the form of training, or it could be in the form of reading the samples. In the case of Ghana, there was a pathologist in Norway who agreed to train the Ghanaian pathologists so that it became possible to get a much quicker pathology report as a result of training. However, in this case, it required North–South cooperation. Efforts should be made to share resources with the low- and middle-income countries.

A second issue raised by Joe Harford was that of tumor banking. The exchange of samples across borders presents significant problems. Each country has its own restrictions on how samples flow across borders. Hypothetically, there is no need to ever ship a sample across a border. All that is required is to have comparable sample collection everywhere, and the equipment to analyze those samples everywhere, and then the information could be shipped across borders. It ought not to be necessary to ship samples across borders, theoretically. This would require a certain amount of standardization. One of the things that the NCI has been engaged in with the bio-banking effort is best practices and standardization, which is an ongoing effort. In order to ensure that there is comparability across borders requires a small number of samples collected in Japan, for example, to be tested in China or the USA, so that you can assure yourselves that comparability has been achieved. Once comparability has been assured then you ought not to need to ship samples. All of the countries that are involved in a network of collaborative bio-banking should be encouraged to work with governments, and perhaps with the WHO, to make these provisions that would at least allow for these small studies in comparability to be implemented.

The term 'comparability' is an interesting word, but it does not necessarily mean uniformity. This particularly applies to informatics platforms and cancer registries and the software that is used for cancer registries. These are not uniform, but they can still be comparable. Databases in particular do not have to be uniform, but it is important to create 'adaptors' that would enable data gained in one country to be usefully compared in another country. It is not expected that the world will uniformly follow US or other standards, but in the interests of collaboration, the opportunity to adapt between systems and be able to compare is essential.

Julia Schneider (NCI, USA) congratulated the Asia Cancer Forum for specifically talking about developing platforms for enhancing collaboration within and outside of Asia. There is tremendous potential in the age of genomics and proteomics to do meta-analysis of large collections of specimens. It is important to ensure that specimens are comparable. After the initial quality control is implemented, it makes sense for specimens to be analyzed in the country in which they were gathered. It is very exciting that these sorts of issues about creating and developing platforms and infrastructure are being discussed in this forum.

With regard to the NCI best practices, the new version is now published and is available on the website for comment. NCI is very actively interested in receiving comments on this new version. The process that was used for developing the NCI best practices was very focused on the USA. It would be good to continue the dialogue about developing standards that can be implemented effectively in both Asia and the USA and other parts of the world. In the USA alone, many challenges were encountered in terms of the way that different institutions were engaging in analysis, both from the technical side and also the ethical and legal issues (informed consent, privacy protection etc.). These issues become even more complex in the context of cross-border collaboration, but it is extremely important to develop and facilitate such international collaboration.

M.A. (University of Tokyo) noted that with cutting-edge IT, it is possible to create information not only for cancer but also for diabetes and other diseases. Lifestyle-related cancer is a chronic disease. The cost for hemodialysis and treatment of cancer is very expensive. It would be possible to use cutting-edge IT to create systems that would be applicable to a variety of lifestyle-related diseases.

I.A.W. (Asian and Pacific Federation of Organization for Cancer Research and Control) reported that in the Southeast Asian context, it is necessary to look at more fundamental issues, because there are discrepancies in the region with standards of health care. There are some parts of the region where there are no people who diagnose or even treat patients. In order to look at the cancer agenda, we need to look at the issue in global terms. For example, take a country like Malaysia, in Kuala Lumpur, there are 15–20 cancer centers within a radius of 25 km, but in other regions, there are no physicians who are qualified to provide cancer care. These are issues that need to be examined. Hospitals treating cancer in the Southeast Asian region have to endure a tremendous burden, where, in some cases, patients have to share beds in a cancer hospital and 200–300 patients are having chemotherapy in a single day. It is therefore important to examine the manpower problem. Part of the issue here is improving the standards of diagnostic care, sharing of pathology and maybe radiology reports through the Internet, but we must also consider how we address the issue of manpower shortage. There are parts of the region where there are no cancer specialists. It is important to think about these important issues of manpower and consider how we can improve this from an Asian perspective.

Andreas Ullrich (WHO) noted that it is important that the Asia Cancer Forum is an open platform for all countries, including low-, middle- and high-income countries. Linking all these countries toward a common goal is extremely important. One of the major drivers in decision-making in the political circles is the availability of data. It is important not only to know how many cases of cancer are occurring, but also to know about the number of staff who are available in each country. Also, we must consider the availability of technology, including diagnostic devices, essential medicines etc. The Asia Cancer Forum could be one that goes beyond the diagnosis of cancer and could be a forum for collecting data about infrastructure. It could provide information through the Internet and other tools could be developed (or are already developed by the WHO) about capacity in countries. This information could then be combined not only for academic purposes but also for a policy forum, where intelligence is translated into policy proposals to politicians. The politicians could then be shown data about incidence of cancer, mortality and survival rates etc. Survival data are very strong drivers in political decisions, as we have seen in Europe. They are not available universally across the Asian region. There is great potential for this forum to set an agenda for what needs to be achieved in terms of political decision-making and will be required to achieve that target.

Massoud Samiei [International Atomic Energy Agency (IAEA)] noted that in order for donors to invest in cancer, it is important to have convincing projects to show that something can be done about cancer. Cancer is perceived as a very expensive disease. The IAEA works with the WHO in many developing countries, including in Asia, to establish cancer centers, and often donors ask about investing in cancer as it is a very expensive disease. In order to get cancer on the MDGs, it is essential to show that there are strategies and solutions that are cost-effective. With a little investment, progress can be made in terms of prevention, screening programs and focusing on specific types of cancer. For this, we have already created examples through the IAEA programs across the globe. The IAEA could collaborate with the Asia Cancer Forum to provide information for the creation of a proposal to submit to the UN. Donors are only interested in cost-effective solutions. The IAEA has pilot projects in eight countries currently and could share these results with the Asia Cancer Forum.

## CLOSING

H.A. and N.K. thanked the speakers and participants for their insightful comments and active participation. In closing, it was noted that the ultimate goal is to utilize advances in innovation to create a large database of knowledge and a global network for analyzing data and sharing information. To this end, it is essential to make efforts to collect all kinds of medical information. The opinions raised at the forum concerning means of sharing data and raising awareness among specialists and patients alike about the importance of medical information in the fight against cancer demonstrated that there is a general awareness of the issue. It was recognized that further efforts must be made to create awareness among specialist organizations of the value and necessity of setting the global health agenda for the sake of scientific development. Approaches must also be developed that enable countries and regions at different levels of development to share data in a comparable manner.

## ROAD TO 7TH ASIA CANCER FORUM

The discussions at the 6th Asia Forum identified a number of key issues that need to be tackled if a comprehensive cancer network is to be achieved. Knowledge gaps exist between the current status of cancer research and treatment in front-runner countries, such as Japan, and the perception of issues in developing and emerging countries. It was recognized that the issue of obstacles to sharing common challenges is one that requires further discussion and analysis. The Asia Cancer Forum will continue to examine means for sharing information in a meaningful and comparable manner. In particular, the role of IT in opening up cancer issues for global health consideration will be focused on in future meetings, with input being sought from policy-makers in government and from the private sector, including pharmaceutical companies. The 7th Asia Cancer Forum is scheduled to be held on 3 November 2010, with invited speakers from the Asian region and major pharmaceuticals coming together to discuss the way forward for a comprehensive cancer network in Asia. With the participation of representatives of academia, government and industry at the 7th Asia Cancer Forum, it is anticipated that the technical issues, specifically relating to knowledge and know-how gaps between front-runner and developing countries, will be further discussed, with a view to crystallizing a future path for a comprehensive cancer information network in the Asian region.

## Conflict of interest statement

None declared.

# Preliminary Linguistic Analysis of Large Number of Medical Incident Reports for Patient Safety

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## ABSTRACT

The analysis of medical incident reports is indispensable for the patient safety. Most of the incident reports include some free composition formats, therefore, the analysis of free descriptions gives new perceptions. We aimed to accumulate, to interpret information again by structured incident information, and to clarify the point that should be improved for the cause of the accident and safe medical treatment improvements in the present study.

We employ the natural language processing to the analysis of medical incident reports in this paper. The network analysis can find various relationships that are not only direct relationships but also indirect relationships. First, some important characteristic words were extracted in three categories of the accident's background, details, and solutions using TF-IDF measure. By using the TF-IDF, we can get some important characteristic words for analyzing the reports. In addition, we show the co occurrence networks using these extracted words.

## 1. INTRODUCTION

"In the shadow of every serious accident, there exist 29 times more minor accidents and 300 times more near misses." This principle was published in 1929 by Herbert William Heinrich, an assistant manager in the technology and research division of an American insurance company [1]. This principle, which hits home the nature of the occurrence of accidents, is taken up in various fields, such as the study of failure, safety engineering, cognitive psychology as well as the study of reliability, and the incident analysis of minor accidents associated with this is recognized as being important in preventing accidents.

Also, the use of information pertaining to medical accidents is important when implementing medical safety measures. The medical safety mechanism of WHO aims to prevent accidents by reusing incident reports through the introduction of IT technology. Harvard University is engaged in the standardization for the collection of medical accident reports and accident information in the risk management consortium. In England, the National Health Service conducts the medical accident/incident report collection project. Even in Japan, the Ministry of Health, Labour and Welfare began the project to Collect Medical Near-Miss/Adverse Event Information in 2001[2]. Through this project, the Ministry conducts analyses based on the collected incident reports.

On the other hand, regarding patient safety, guidelines for the future deployment of incident analysis are set out in WHO's International Classification of Patient Safety (ICPS) [3]. ICPS states the necessity of first investigating the adequacy of classes of incident case studies such as those mentioned above, and second, methods of expressing incidents that adequately reflect these classes, i.e., it states the necessity of ontological construction. In this research, in line with WHO guidelines, we conducted an analysis regarding the adequacy of classes in case studies collected in the Project to Collect Medical Near-Miss/Adverse Event Information and the tendencies of description that aim at ontological construction.

In the Medical Near-Miss/Adverse Event Information including the abstract, background, and solution for a single case are described using a free composition format. In this paper, we analyze the large number of medical incident repots (more than 15,000 reports) provided by Osaka City University using the natural language processing and the network analysis. By using natural language processing, an understanding of the tendencies of description as well as guidelines for future ontological construction can be acquired.

The remainder of this paper is organized as follows. First, we describe the dataset of the medical incident reports provided by Osaka City University. Next, we describe the methodology based on the Natural Language Processing and the Network analysis for analyzing the large number of medical incident reports. Then, we present the results of analysis of incident reports. Finally, we present our overall conclusions.

## 2. MEDICAL INCIDENT REPORTS BY OSAKA CITY UNIVERSITY

### *2.1 Overview of Medical Incident Reports*

With increasing social demand for the prevention of medical accidents, the Health, Labour and Welfare Ministry started the Project to Collect Medical Near-Miss/Adverse Event Information from 2001 in order to collect and analyze incident case studies and to provide information conducive to medical safety, such as measures for improvements. When the project was first started, a framework was in place in which the Pharmaceuticals and Medical Devices Agency collected incident case studies from participating medical institutions and then reported these case studies to the Health, Labour and Welfare Ministry, following which a Health, Labour and Welfare Ministry study group conducted aggregate calculations and analysis. The 1st–10th collection of incident case studies were conducted following this framework, and information based on these collected incident case studies was provided by the Health, Labour and Welfare Ministry. From 2004, the Japan Council for Quality Health Care took over the collection of incident case studies, collecting case studies from the 11th collection [4].

Osaka City University also collected 18,340 incident reports from 2007 to 2010. In the incident reports provided by Osaka City University, free composition formats are taken quite seriously compared with ones provided by other Hospitals. For instance, the average number of words in the incident reports by Osaka City University is 188 words, on the other hand, the one by the Project to Collect Medical Near-Miss/Adverse Event Information is 80 words[2]. In fact, doctors and nurses in Osaka City University have to input the reports for the free descriptions at first because of the Layout of data entry screen.

### *2.2 Data Sets*

We used free composition format written in Japanese relating to medical agents from 2007 to 2011 by Osaka City University. The number of documents is 18,340. Each case study is in a free composition format, with the abstract, background, and solution being approximately 188 words long, respectively. In addition, the two classes of medicine and accident are granted to each case study. With regard to the class of treatment, there are six classes of general drug, preparation of drugs, drowsy of drugs, contraindicated drug, chemo treatment, and other drug; with regard to the class of operation, there are the nine classes of name of drug, amount of drug, regimen, amount and regimen, flow rate, drug sensitivity, diapedesis, forget to dose, and object person. With regard to the class of treatment, as all the classes of operation do not exist, there are 32 cross classes that cross calculate the class of treatment and the negligent class of operation.

When describing accidents in a free composition format, the reporter makes every effort to include every single circumstance. We can say that extracting important information from these circumstances means creating a foothold for a bottom-up type of ontological construction. Results obtained from this and links with classes granted top-down is in accordance with the future guidelines for incident analysis sought by ICPS.

## 3. METHODOLOGY OF NATURAL LANGUAGE PROCESSING AND NETWORKD ANALYSIS

### 3.1 Methodologies for analyzing the incident reports

In this paper, natural language processing was first conducted on the incident reports. Keywords that emerge characteristically were then extracted for each category of "background/causes," "details," and "solutions," using the tfidf method. After that, the semantic tendency of the incident report was investigated in order to create a network of words by calculating the co-occurrence information of the words using the Jaccard coefficient.

Also, we show the networks among each document which are determined by the similarities between documents based on the tfidf method. As natural language processing contains a lot of noise, there is a need to conduct preprocessing in order to obtain characteristic words that can be used in determining links.

### 3.2 Japanese language morphological analysis

In the first stage of preprocessing, we conducted morphological analysis in order to break down reports into words. Morphological analysis is a method used to delimit each word in the text where words are not delimited by spaces, such as in languages like Japanese [5]. In this research we used MeCab, one of the most common engines for conducting morphological analysis [6].

There is the possibility that words obtained using MeCab are too finely classified to conduct the analysis of links. Therefore, we connected words using the following methods and used them as new words.

We connected words using information on the parts of speech. The above-mentioned MeCab not only breaks down words but also grants major classes and minor classes relating to parts of speech. In cases where the minor class of parts of speech of certain words was a suffix and the word before it was a noun, these two words were treated as one word.

Next, we connected words based on the number of word occurrences [7]. Let us envisage a situation in which two words -hereafter called A and B- appeared consecutively. If we designate the number of word occurrences in instances where each word is considered separately as *n (A), n (B)*, then the number of word occurrences in which they appear consecutively is expressed as *n (A∩B)*. In cases where *n (A∩B)/min (n (A), n (B))* exceeded the threshold value (*0.1* in this research) then we treated those two words as one word.

In the documents, nominalized verbs, general nouns, and proper nouns were targeted. Focusing solely on nouns is the method generally used in extracting characteristic words. Moreover, in the case of official documents in Japanese, as many of the verbs are nominalized, a lot of information can be obtained regarding action even if using only nouns.

### 3.3 TF-IDF Method

In this research, we calculated a value called *tf-idf* from the frequency of occurrence and conducted filtering based on this values. *Tf-idf* is one of the most widely used indices in extracting characteristic words for document classes and in cases where a certain word occurs several times in a small number of documents, it is defined so as to enlarge that value[8]. *Tf-idf* is calculated as follows:

$$tf-idf(t,d)=tf(t,d)\times idf(t) \quad (1)$$

$$tf(t,d)=n(t)/\sum_{k\in T} n(k) \quad (2)$$

$$idf(t)=\log|D|/|\{d:d\in t\}| \quad (3)$$

Here, $t$ is a term, $d$ is a document, $n(t)$ is the frequency of occurrence of term $t$, $|D|$ is the total number of documents, and is $\{d:d\ni t\}$ the number of documents in which word $t$ occurs. $T$ means the set of terms.

The *tfidf* of general words occurring in a large number of documents has a tendency to be of a low value, although words among even general words that have an abnormally high *tf* in some cases exceed the filter effect of *idf* and assume a high value.

### 3.4 Creation of Co-Occurrence Networks

The co-occurrence index is generally used as a method for finding links from the degree of similarities between words in documents. Here, the simplest co-occurrence index for finding links between the two word A and B is the number of

co-occurrence $|A \cap B|$ for two words. Here, $|A \cap B|$ is the number of characteristic words that exist in A and B. If considered with only $|A \cap B|$, there are problems such as including as many characteristic words as in long texts and links with other documents being displayed as high. Consequently, a number of co-occurrence indices that improve on these points have been proposed, with representative indices including the Jaccard coefficient [9].

$$Jaccard: |A \cap B| / |A \cup B| \quad (4)$$

A link is established between the two words in the event that these indices exceed the threshold value.

## 4. PRELIMINARY ANALYSIS RESULTS

Table1: Top 10 Characteristic Word in Incident Reports (*TF*; Term Frequency)

| (TF) | Background | Details | Solutions |
|---|---|---|---|
| 1 | Patient | Report | Check |
| 2 | Check | Patient | Time |
| 3 | Drug | Check | Patient |
| 4 | Nurse | Attending Doctor | Direction |
| 5 | Direction | Monitor | Drug |
| 6 | Internal use | Duty Doctor | Explanation |
| 7 | Infusion | Doctor | Nurse |
| 8 | Pill | Direction | Thoroughness |
| 9 | Room | Nursing | Drug maker |
| 10 | Administration | Explain | Doctor |

Table2: Top 10 Characteristic Word in Incident Reports (*TF-IDF*)

| tf-idf | Background | Details | Solutions |
|---|---|---|---|
| 1 | Drug | Patient | Check |
| 2 | Patient | Report | Time |
| 3 | Check | Attending Doctor | Patient |
| 4 | Internal medicine | Check | Direction |
| 5 | Direction | Doctor | Drug |
| 6 | Nurse | Monitor | Explanation |
| 7 | Administration | Apologizing | Nurse |
| 8 | Infusion | Nursing | Thoroughness |
| 9 | Root | Duty Doctor | Before |
| 10 | Channel | Direction | After |

The top ten characteristic words that appear in the incident report such as "background/causes," "details," and "solutions" with *tf* (term frequency) are shown in Table 1. The top ten characteristic words that appear in the incident report with *tf-idf* (Eq.(1)) are shown in Table 2. Under the category of "Background," the words "Patient" "Check," "Drug," "Nurse," and "Direction" rank high in Table 1. Moreover, the fact that the word "nurse" ranks high shows that there are many accidents related to nurses. Under the category of "Background," the words "Drug" "Internal medicine," "Infusion," and "Channel" rank high in Table 2. Therefore, accidents related to medicines are important for analyzing the reports. Also, the words "Check," "Direction," and "Explanation" rank high under the category of solutions. In addition, the words related to the medical process such as "before" and "after" are high rank.

One word such as "lack," "confirmation," or "drugs" alone cannot express the tendency of the accident. In this research, co-occurrence networks of words were created by connecting the words that co-occurred with each other at a high frequency. The degree of co-occurrence is calculated using the Jaccard coefficient[3] shown in Section 3.4.

Figure 1 shows the networks of characteristic words created using the accident reports related to incorrect drugs. Each node represents a word, and an edge represents the intensity of the co-occurrence between the words. First of all, in viewing the network for "background/causes" (see Figure 1 (a)) it is clear that the network is created around the word "Check," and one can see that the cause of many accidents is the fact that the "Check" on "drugs," "Patient," by "Nurse". Connecting the words that co-occur frequently allows us to understand what tends to become inadequate. In the network of "accident details" (see Figure 1 (b)) many different words appear at once, indicating the presence of diverse accident details. Viewing the network for "solutions" (see Figure 1 (c)), as with the network for "background/causes," it is created around the word "confirmation."

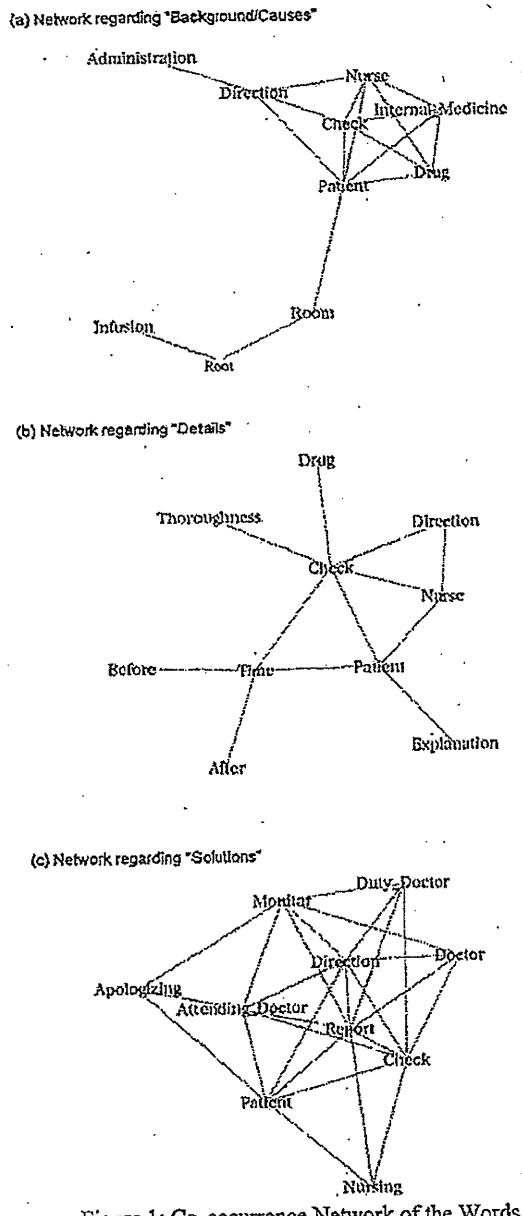


Figure 1: Co-occurrence Network of the Words in Incident Reports

## 5. CONCLUSION

In this paper, the characteristic words were extracted by analyzing incident reports, and the co-occurrence networks of the characteristic words were created. As a result, the language networks with the hub of the word "check," thereby revealing that inadequate confirmations on the drug labels, instructions of a physician and patient were very significant causes of accidents. These results suggest the effectiveness of introducing the network analysis method. In the future work, we would like to focus on the medical repots for improving the notational rules for the names of drugs and dosages in incident reports. Also, we would like to analyze the differences of understanding of the incident reports between positions like doctors, nurses, pharmacists.

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# Healthcare IT System not Only Prevents the Medication Errors But Also Improves the Patient Safety with Evidence

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## ABSTRACT

The purpose of this study is ensuring patient safety of blood transfusion by minimizing risk of transfusion at the point of care through Information Technology. The targets are ensuring five rights of transfusion, rights process and right information by auto identification and traceability of blood products. Auto identification and data capturing system with RFID based on the Point-of-Act-System (POAS). It provides real time right identification, process management to ensure right medication and traceability with serialized number in single item level. The system designed based on process analysis and use case of transfusion was successfully implemented in Red Cross Hospital to prevent transfusion errors and ensure traceability of blood products. By reading RFID at the point of care, we can check database to look for adverse events of blood products. We identified all 377 blood products and acquired tracking data successfully. We can improve patient safety and traceability with RFID.

## 1. INTRODUCTION

Many hospitals and blood centers have introduced barcode and RFID systems for patients and blood identification and they have contributed to reduce incorrect blood products and transfusion [1-6]. However, present identification of patient and blood with these technologies doesn't ensure all of '5 Rights' for safe medication. "5 rights" means right patient, right product, right dose, right root and right time administration of medication. 5 Rights are regarded as an essential factor for ensuring medication correctness and Barcode and RFID are fundamental technologies for achieving the purpose. It is better strategy to keep transfusion safety that blood transfusion system should move their focus from patient identification to comprehensive 5 rights identification. In addition, barcode and RFID have more capabilities to improve patient safety through managing process of activities and traceability of blood products as well as ensuring 5 rights identification at the point of care. Medication is not a single activity that is independent from other activities but a process that consists of connected a series of activities by various workers. It is crucially important to keep good communication among medical workers and ensure rightness of medication process without any omissions and faults. This is another area of contribution of barcode and RFID based administration system for patient safety that barcode and RFID can contribute by capturing and documenting accurate data of activities by medical workers that has a capability to facilitate high quality communication based on real-time accurate information. Good communication based on real-time information prevents miscommuni-cation and misunderstanding and can promote patient safety. Traceability of drug and other materials is also achieved with barcode and RFID administration and data capturing at the points of production, transfer and consumption. In medical setting traceability of materials has been widely recognized as necessary piece for enhancing patient safety. Traceability enables us to find harmful drugs and materials with perfect information of their original production points and path ways of transfers.

## 2. METHODOLOGY

The purpose of this study is ensuring patient safety on blood transfusion by minimizing risk of transfusion at the point of care with Information Technology and implementing a system to conduce it. To minimize risk of transfusion, there are three important components achieved by identification

and data capturing. First one is securing 5 rights of transfusion by auto identification at the point of care with right information. Right information is basic factor for right identification and the information should be update in real time based upon the change of situations including clinical settings. Second is securing right processes of transfusion. Skipping process of transfusion including cross matching and incorrect processes of transfusion might make transfusion harmful. Third one is traceability that enables checking information of adverse events of products that are prepared from same bloods. In terms of blood transfusion safety, window period is important concept to be considered. Window period is a term that test can't find virus or other harmful source after infection. The window period of Hepatitis C Virus is 23 days by Nucleic acid based tests (NAT) and 82 days by Antibody test (AB test). There are risks that infected blood products passing test during window period would be distributed to hospitals.

The way to handle the risk that infected bloods would be distributed is traceability of blood products by single item level. If there is knowledge about when and where these bloods were collected and produced, we can prevent secondary infections by recalling blood products prepared from same original immediately.

However, there is an issue to achieve perfect traceability of blood products that is tradeoff between public safety and privacy data protection in this situation. In contrast to drug traceability, perfect traceability of blood products is including highly private information such as infectious information of donors and there is a possibility to like the information to a specific name. Collecting information on blood products has a possibility to be a threat for donor's privacy. Solution for this tradeoff is also required to implement traceability system and our target in this study.

1) *Point of Act System*: POAS captures complete data on each medical action including 6W1H information (When, Where What, Why, for What, to Whom and How) conducted in the hospital. The units of data recorded by the system are: Who—the implementer (the person who initiated the order, or the person who carried it out), to Whom—the patient, How—medical activities and changes in them, What—materials used (pharmaceuticals, medical materials and others), How much—amount of materials used and number of applications, for What—name of patient receiving medical services, When—date the order was placed, implemented and discontinued and the activities that were implemented, and Where—place of implementation (department, hospital, ward, etc.). The collection of complete data including 6W1H information is an innovative source in understanding actual situations directly without estimation or bias, and enables the investigation of solutions to prevent error [7,8].

2) *Complete data:* POAS data is "Complete data" that capture every action by real time and quite accurately. This means the data captured by the system has full traceability of drugs and materials and can be used for analyses on healthcare management. Complete data provide us great opportunity to analyze situation of healthcare management, quality and safety without any sampling methodologies to estimate original value. That makes reliability of analyses higher. In addition, complete data is especially useful for patient safety researches, because complete survey is necessary to estimate medical error and accident rate.

3) *Process Management:* Structure of POAS data capturing is based on process management of each medical action. Process management structure requires every medical workers capture data at their point of action. Without capturing data on completion of activities, medical workers can't do next activities on the medication process. It enables POAS to acquire every result of medical action and assure capturing complete data.

4) *Settings:* Our experimental project was enforced in Iwate Red Cross Blood Center and Morioka Red Cross Hospital as Table1. We created the system for auto identification and data capturing from blood collection in the blood center to administration in the hospital with POAS and RFID. The system put time stamp with the data to

ensure rightness of information and consistency of process order in capturing data.

5) *Single item management from production to consumption with SGTIN:* Serialized number was put on RFID to distinct each blood product with single item level. Serialization of blood products is essential factor to distinguish one blood from others uniquely. If a number was used for more than two objectives, it makes difficult to confirm an object uniquely.

6) *Certification system for safe blood transfusion and electrical data capturing with RFID:* This system was aimed to confirm 5 rights of transfusion at each point of transfusion. 5 Rights in blood transfusion is right patient, right blood, right unit, right root and right time. Right blood in this setting includes five additional components with checking product ID. At the point of checking, this system certified types of product including Blood Red Cell, plasma and blood plate, blood type appropriateness, completion of cross matching, result of cross matching and adverse event information of products from same donor. In concrete, system that is possible to verify information of infected blood products founded just 2 minutes before in other hospitals. Table I shows comparison of verification component with other blood transfusion systems. Exciting systems had focused on Blood type certification and some systems had tried to integrate transfusion system with blood test laboratory system to check the results of cross matching at laboratory.

Experimental project with the system described above was implemented in Morioka Red Cross Hospital and Iwate Red Cross Blood center. The experimental period is from 30/07/2007 to 30/11/2007 for 4 month. Object departments in Iwate Red Cross Blood Center are department of Testing, Preparation and Delivery. Objective departments and wards in Morioka Red Cross Hospital are wards of digestive tract internal medicine, General Medicine, Surgery and Testing Department. The number of blood products used in these 3 wards is 75% of total usage in all hospital. Though the object wards are three, it is enough to investigate feasibility of the system in these three wards. We operated 377 blood products with RFID during the term.

Table1 Comparison of Auto Identification with Other Systems

| | Exiting Administration System | POAS System |
|---|---|---|
| Blood Type Certification | Possible | Possible |
| Completion of Cross Matching | Partially Possible | Possible |
| Checking results of Cross Matching | Impossible (Need additional procedures) | Possible |
| Checking adverse event information by database located outside hospitals | Out of Focus | Possible |

## 3. RESULTS

We analyzed process of transfusion in Morioka Red Cross Hospital and Iwate Red Cross Blood Center to identification and track appropriately. Transfusion Process could be divided into two major parts, blood center and hospital, based on the place. In blood center, staffs in blood center collect blood from donors and deliver it to department of preparation. Department of preparation receive the blood and test blood for screening whether the blood is appropriate for blood products or not. Department of preparation prepare the blood passed screening for products and form products to deliver to hospitals. At this time, blood is ready for use for blood transfusion and wait for requests from hospitals.

On the other side, in hospital physicians order transfusion for patients and nurses receive the order and request blood products to department of testing. This order was made junction with blood delivered from blood center and department of testing in hospital operate cross matching. If the result of cross matching shows appropriateness for transfusion, the blood delivers to the point of transfusion. And in a ward or operating room, nurses or physicians administer the blood to patient. In this sequential process, there are movements of places and many actors engage to this process to operate transfusion. Figure 1 shows normal process of blood transfusion in the hospital. This is not

only case to be treated by transfusion system. We analyzed transfusion process in the hospital to find every type of process to cover all case of transfusion. Each process shaped into use case with UML and there are 14 types of use case for transfusion process.

These use cases can be classified with 4 major categories; Ordinary, Cancellation, Warning and ex post facto. In ordinary process, transfusion operation with blood stocks and without blood stocks are regarded as different use case, because interactions and movements on information and products are different in each use case. Similarly, in cancellation, the activities and information to be interchanged are different based on the timing of cancellation. Ex post facto means information was entered after injection because they are used after office hour and testing department was closed.

The important thing to achieved 5 rights transfusion with IT is feasibility of the system and information. In this system all certification was operated with just one data capturing by the point of action. In verifying information, system refers original data captured or entered at the point of actions.

In this system, we can check completion of cross matching without fail by process management technique. In designing system, we analyzed process of medical activity and described as nonreversible process that is a series of medical activities.

We described all patterns of blood transfusion process by process analysis methods. In normal transfusion process, flow of process from physician's order to administration goes thought without hitch. However there are other patters including emergency cancellation and rejection of blood products. By describing all patterns of use case, it is possible to construct the system can handle all occasions without any exception. This feature is especially important for traceability. Use case 1 (Transfusion operation without stocks) is the most common use case, because the blood center is located on next to the hospital and they don't need to have a lot of stocks. Use case 2 is usually the most common case in hospitals. In use case 1, three actors including physician, technician, nurse and staff in blood center operate the process. At first, physician makes a decision on transfusion and order transfusion. Nurse receives the order and delivers the order to testing department. Technician starts preparation for transfusion by request to blood center, because they don't have a stock in the hospital. Technician receives blood products from blood center, operates cross matching and delivers it to ward or operation room. Nurse operates the transfusion.

Our system was created based on these analyses on process of transfusion with use cases. Every type of transfusion except use case 14 was target to ensure traceability of blood products. Figure 4 shows overview of our system. In hospital, transfusion process was managed by Transfusion management server and Hospital information / CPOE server. In blood center, transfusion process was managed by public server and donor server. At he each point of process, actors read RFID to capture data on 6W1H and auto identification with PDA and computer. Transfusion server connected to public server in hospital through internet (VPN). This connection makes possible to manage whole process from production to bedside.

The ID on RFID was rewritten after preparation. Information to link donor ID to product ID was securely managed inside blood center and blocked physically and nobody could refer to this server from outside. The process of rewriting was also under process management and the process can't be processing without rewriting.

By connecting hospital system to public server in blood center through internet, it is possible to certify availability of blood products by original product database including adverse event information in real time. When nurse identified blood product at the point of care, PDA checked adverse event information in blood center database trough middle ware as well as patient information and product information. All transaction for identification to ensure 5 rights and right process was completed within 2 seconds. If some infected blood were found at other hospital and the information was putted in public

server, right after the time PDA warn usage of the blood products prepared from same source. By this system, nurses can check safety of transfusion from the various points of view by just one reading RFID with PDA within 2 seconds. It is effective to improve patient safety and operation of nursing works.

We evaluated the system based on data captured by this system. We proved that the system with the RFID tag and SGTIN was able to manage the pharmaceutical drugs at the single item level in real time, and improve patient safety. For all 377 blood transfusions captured by this system, data was perfectly collected and there is no inconsistency on the data. For patient safety, it is very important that the response of the information processing is quick to operate the real system. We accessed the data center in Nagoya City, central Japan, away at 900km from the hospital in Morioka City in the Tohoku region, north-east Japan, through the Internet line. As a result, the processing time of the system was within 0.4 seconds, and thought to be a response enough by practical use also at each stage. Moreover, both access times were the response within one second, and it was thought enough though the access from the wholesale enterprise in Morioka City was an access to the data center in Nagoya City that used the connection of the Internet of a very narrow band up to 402 kbps by Personal Handy-phone System. To evaluate data captured by the system, we drew the data as traceability graph. An example of traceability graph is Figure 2. Horizontal axis shows time flow and vertical axis shows flow of blood products from production to consumption. There are two lines before delivery. Left line shows blood product flow in blood center. Before delivery, blood products don't timed with any special patients. Right line shows flow of transfusion order by doctor. Followed by the order, a blood product was matched with a transfusion order at the point of delivery. From the point, Product ID is associated with Patient ID. The advantage of describing traceability graph is showing result of data capturing visually and easily. If data capturing system worked correctly, data capturing point is going right with process progressions. If the line is going left, there are some problems on data capturing such as ex post data entry, delay of the system and time lag among systems.

The result of describing 377 traceability shows the system ensures traceability for all blood products from production to consumption. Certification at each process was successfully done. During the experimental period, there is no accident and medical mistakes on blood transfusion. At the level of the business load, in the entire work, each person in charge is skilled in a new system and we improved the operating effectiveness of the person in charge more than existing business. In terms of checking prescription and mixing injection drugs, we have double check system now. In near future, we can make up single check system with RFID tag system for backup.

Moreover, we proved the expectation of the effect of the medicine of the abandonment amount reduction, and contribution also improved management and the $CO_2$ exhaust amount reduction of the medical institution.

As a result of the operation switch verification at the failure, we confirmed the operation switch was able to be done promptly, and there was no big influence on the hospital work. We expect that applicability of the RFID tag is able to have the good effect of the batch reading in the business of confirming a large amount of medicine.

## 4. DISCUSSION

We constructed system with internet and RFID to manage whole processes from production to consumption of blood products to expand the capability of certification system and ensure traceability. Many previously published literatures have been tried to construct certification system at the point of care for blood transfusion or at blood center to make right documentation of blood products for blood safety and management [1-6]. Compare to these systems, this system has several advantages that other systems don't have. This system ensures 5 rights of transfusion and right process and information with real time original information. By checking original data base

through middle ware at the point of care, the correctness of information for certification is highly secured. This technique makes us possible to check the original database to certify patient information and blood products with electrical medical records and computerized order entry system directly and find adverse events information on blood products through internet.

We tried to evaluate improvement on blood transfusion safety and traceability with this system. The number of medical accidents and incidents on blood transfusion from April to June 2007 (before implementation of the system) is zero and the number of them during experimental period is also zero. This information didn't provide us evidence of improvement on safety based on number of accidents. These data about number of accidents were based on voluntary reports by medical workers. Therefore, it is impossible to find any accidents if they don't report medical accidents. However, administration systems have possibility to provide new opportunity to evaluate and measure level of safety. Warning logs by reading wrong patients and blood products RFID means that there is a possibility that the administration for the patient would be accident or incident without administration system. The data captured by the administration system has a potential to measure the level of safety and comparison of the data between before and after implementing interventions for patient safety is our next target for researches.

Costs including work burdens of medical workers are sometimes the highest obstacle to introduce health IT system [9-10]. It is useful to investigate feasibility of the system by evaluating change of time to finish each activity [11-18]. We investigated time to finish each activity by collecting data observationally and computed average length of time from around 10 observationally data of each activity. We compared length of time to finish each activity between using this RFID based administration system and using paper based communication and documentation. We chose six activities for comparison and six activities are blood receiving, decussation testing and stock taking in the blood center and delivering to wards, certification before administration and recording administration in the hospital.

For all 6 activities, the time to finish each work with RFID is shorter than with paper based system. Works of nurses and technicians would be also effective as well as safer by introducing RFID based traceability system. Especially time for administration of transfusion is decreasing. This system has a possibility to improve productivity of transfusion process as well as transfusion safety.

Another way for identification and data capturing used widely is barcode technology. RFID is superior to traditional barcode technology in numerous ways [15,16]. RFID does not require line-of-sight, allows simultaneous read of multiple tags, is able to store more information on the chip, cab include sensors for condition monitoring such as time and temperature, and enables automatic identification and data capture [15]. In addition to these operative advantages, RFID enable rewriting information and it is significantly important to construct a solution for privacy data protection and future extensions.

We investigated and focused improvement of transfusion safety with auto identification and data capturing system. In addition to these advantages, it also has possibility to provide significant advantages on hospital management and regional health system management. The ways to storage blood products were strictly regulated, because quality of blood products is easy to change with affects from outside. Red blood cell products must be stored inside refrigerators having a function to record temperature and blood platelet must be inside storage with vibration system. They require strict methods to store and blood products delivered once were regarded as consumption and sometimes wasted. Blood products are scarce and valuable resource from human blood, and waste of blood products might cause safety and management problems in hospitals and regional healthcare system. Traceability data can contribute to solve these issues by visualizing data of distributed blood products. That would enhance effective use of blood products

by connecting hospitals to blood center and among hospitals.

## 5. CONCLUSION

In this study, we focused on identification and data capturing for patient safety. Capturing data and alibi management of materials including blood products leads to effective use of resources as well as improve patient safety as mentioned above. We can certificate each medication and capture those data at the same time, contribute to patient safety and improve health care delivery. To be a trusted system, the systems have to use right information and consider securities of people. Trusted IT system can contribute to patient safety, effective use of blood products, reducing waste that might be essential factors for trusted health care system.

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# Information Technology in Health Care

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