Introduction

Health information technology (IT) and electronic health records (EHR) have the benefits of improving the quality of patient care, work efficiency of healthcare professionals, and satisfaction of patients as well as providers (1). However, the different levels of health IT adoption and its integration into hospital workflow can affect the maximization of the benefits of using of health IT. The implementation and use of health IT includes various challenging organizational aspects in terms of the structure of healthcare organizations, tasks, people policies, incentives, and information and decision processes (2).

This article is aimed at sharing the experiences and main achievements over 13 years of implementing hospital information systems (HIS) that include comprehensive EHR systems and patient-centered smart hospital applications in a tertiary university hospital, Seoul National University Bundang Hospital (SNUBH) in South Korea. SNUBH opened as a fully digitized hospital in May 2003, free of any paper-based medical records and with a homegrown EHR system. It was accredited as a HIMSS Analytics EMR Adoption Model Stage 7 hospital in October 2010. Notably, SNUBH was the first hospital outside the US to receive...
Stage 7 accreditation, a rating that was revalidated in March 2016 with the optimal use of health IT. Thus, our use of health IT to maximize its benefits and provide patient care in a more comprehensive manner would be expected to be helpful in adopting health IT systems and designing new innovative applications to other healthcare organizations.

**Applications of a HIS**

SNUBH’s HIS, named BESTCare, “Bundang hospital Electronic System for Total Care”, is an integrated system of comprehensive applications for direct care and support care of outpatients, inpatients, intensive care units, emergency room, and operating room units (3). Figure 1 shows the health IT adoption journey of SNUBH with the recent development of the next generation HIS, BESTCare 2.0, based on the latest IT and a rich user information platform.

**User-centered EHR & clinical decision support systems (CDSS)**

As the clinician’s user experience and satisfaction with the EHR system is one of the challenging barriers to health IT adoption, the BESTCare 2.0 system was re-designed to meet the increasing demands for ease of use and the ability for users to set preferences. The presentation of information in terms of layout and structure is important because it can influence data retrieval, interpretation, and clinical decision-making. Thus, we aimed at improving users’ work performance and satisfaction by providing a personalized, optimized, and common user interface (UI) to very busy clinicians.

By applying a user experience design methodology and analyzing over 3,000 requirements and new ideas collected from hospital users, we derived and implemented several key concepts as outlined below:

(I) A patient journey map and patient summary sheet: a patient journey map shows all patient-related longitudinal events in the outpatient clinic, inpatient department, emergency department, and various examination suites in a visualized form. The patient summary sheet shows all the medical information about an individual patient, such as their history of surgical procedures, diagnoses, discharge summaries, test results, and medications.
The tools enable medical staff to understand complex patient information at a glance;

(II) Embedded picture archiving and communication systems (PACS): in order to increase the usability of accessing image testing, PACS was embedded into the EHR. Therefore, physicians do not need to open an additional popup window to view PACS. Different images, such as cardiology PACS and radiology PACS, can be easily and efficiently compared in a single window;

(III) Flexible and interactive UI: using the window tile function, each user can configure and use his or her own UI rather than using fixed, common UI;

(IV) UI based on full high-dimension (HD) and a wide and large monitor: the large and wide single monitor can help medical staff to effectively review various and complex medical information;

(V) Unified communication (UC) integrated with EHR: the integration of communication tools, such as telephone, email, cell phone, messenger, video call, and video conference systems, into the EHR system, enhances communication between co-operative users in real time.

A CDSS combined with an EHR system prevents human error during order entries and helps clinicians to make a decision on diagnosis and treatment with the latest scientific evidence, resulting in improved patient safety and quality of care.

Using a CDSS rule engine, we have implemented and supported several types of rules, such as overlapping prescriptions, drug-drug interaction, renal dosing guidelines, overdose prevention, contradictions for age, pregnancy, and breast feeding, and drug-disease interaction.

In addition, clinical pathways (CP) integrated with the EHR system can ensure standard care with best practice and expected care processes. Through a CP task force team of doctors, nurses, pharmacists, a health insurance review team, and IT experts, we designed and implemented over 150 CPs from 13 departments. This resulted in a CP application rate of over 85%, achieved by active participation from hospital staff and periodic monitoring/feedback and modification processes.

Patient safety with barcode enablement

Real-time documentation and cross-checking of care practices in the EMR using radio-frequency identification (RFID) and barcode technology have the potential to ensure patient safety, increase work efficiency, and improve care processes. It can reduce the administrative workload for nurses giving them more face-to-face time with patients, thus increasing patient satisfaction.

In SNUBH, RFID wristbands containing patient information were issued to inpatients. Then, the closed loop medication administration (CLMA) system using RFID and barcode technology was implemented in several areas: pharmacy, medication administration, blood bank, and a communal space storing human milk.

The RFID and barcode system enabled a hospital environment where care practices provided to inpatients could be conveniently and accurately documented by cross-checking patient information with medical orders. Furthermore, the delivery or transfer of medication, specimens, and materials could be tracked real-time. This traceable system improves the quality of care, prevents medical errors, and promotes efficient use of resources by emphasizing accountability.

Care coordination using n-device strategies

Mobile access to EHR systems anytime, anywhere, and from any device is essential for effective access to patient’s data and effective communication among healthcare professionals and patients. With n-device strategies for smart and mobile hospitals, we adopted and implemented the virtual desktop infrastructure (VDI), mobile EMR system, and large touch-screen based dashboard system.

The enterprise-wide adoption of cloud-based VDI allowed healthcare professionals to access the EHR system with full functionality outside the hospital. It also enabled nurses to visit a patient’s home without any paper/printed records and to both access and capture patient’s data on site, resulting in improved quality of care, reduced paper resources, and efficient access to medical records.

The mobile EMR system had features such as accessibility to most of the EMR data, including medical images, by integrating Mobile PACS, an easy-to-use UI, and support of all devices regardless of OS, as well as enhanced security with mobile device management (MDM) solutions.

The dashboard system on a 55-inch touchscreen monitor is a concise and context-specific display system showing all the clinical and business data in text, graphic, and image form on a single screen with at-a-glance view to facilitate ease of understanding and mutual communication between healthcare personnel and even with patients and family
members. It has been utilized in wards and ICUs for
team rounding, education of residents and students, and
explanation of a patient’s medical status to patients and their
families. It can also be effectively utilized for research that
requires a group discussion and also a case conference for a
collaborative study.

Data analytics & research support
For the use of EHR data in monitoring the quality of
patient care and patient safety, as well as supporting clinical
research, we implemented a clinical data warehouse (CDW)
system. As demand for clinical quality improvement
increased, we developed clinical quality indicators based
on the CDW from 2005 and upgraded it with in-memory
computing appliance in 2013 for faster access and search
capability. Since its implementation, additional indicators
including a 6-sigma indicator, clinical pathway indicator,
performance indicator, customer indicator, quality medical
record indicator, and infection control and insurance
management indicators were further developed, maintained,
and managed, resulting in over 400 electronic clinical
indicators utilizing its CDW. As one of the many uses that
contributed to improving the quality of patient care, the
system was able to maintain optimal dosages of preoperative
antibiotics by giving feedback of preoperative antibiotic
prescription through continual monitoring (4).

The CDW system that provides big data analytics tools
based on in-memory database technology enables better
support data retrieval, extraction, and analysis for research
as the big data issue is becoming a challenging research
topic in healthcare. Thus, the CDW system included
functions to retrieve unstructured medical records with
free-text search and scenario-based retrieval of EMR data
with a user-friendly interface.

Patient engagement using mobile technologies
Patient participation and engagement is significant in
upholding the continuum of care and improving patients’
health by empowering self-management with greater
information sharing. With the aim of reinforcing patient
engagement, we developed various patient-centered systems
using mobile technologies, such as personal health records
(PHR), a smart survey system, and a smart bedside station
system.

The patient portal and PHR app (5) provided patients
with a personalized health record on their PC and smart
devices, showing their medical records, medications, and
laboratory test results. Patient-generated data such as
weight, blood pressure, glucose, diet, and exercise was
captured and stored into the EHR system, facilitating
seamless communication between medical professionals and
patients.

The smart survey system digitized and integrated self-
administered questionnaires to assess patient condition
and was utilized in various clinical departments including
pediatric neurology, rehabilitation medicine, and oncology.
As the questionnaires were completed by patients on
various mobile devices and PCs in outpatient and inpatient
settings, the questionnaire responses appeared as part of the
respective patient’s EMR, thus enhancing the quality of care
by providing physicians with more comprehensive data and
by engaging physicians through a more responsive process.

The smart bedside station system (6) is a personal
concierge device on all inpatient beds that provides
entertainment services, internet access, and educational
content customized to each patient’s diagnosis and treatment.
Patients have access to relevant information about their
treatment such as their current medication and examination
scheduling and objectives. It empowers inpatients by giving
them more information and creates a new channel for two-
way communication between medical staff and patients.

Conclusions
From our experiences on the use of health IT at SNUBH,
one of the success factors for achieving the adoption of
health IT is that hospital staff and end-users of the system
should be actively involved from the beginning of driving
user requirements until the end of testing. It can effectively
reflect end-users’ needs and workflow in the system, thus
improving user satisfaction and experience.

The future use of health IT will be advanced with state-
of-the-art mobile technology and Internet-of-Things (IoT), big data analytics, and cloud computing to provide
personalized, preventive, and predictive care to patients.

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Footnote
Conflicts of Interest: The authors have no conflicts of interest
to declare.
References