

**Project Title: Healthcare systems process improvement using NFER technology**

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**Summary**

The object of this study is to improve the healthcare delivery process in an intensive care unit (ICU) by using data from a real-time location tracking system. Although ICU nurses experience a high workload every day, it is hard to improve the workflow because of the dynamic uncertainty of their tasks. To advance our understanding of the ICU nurses' workflow, we used Near-Field Electromagnetic Ranging (NFER) sensors as a real-time location tracking system. The data from NFER was combined with manual observation data. This novel approach allowed us to analyze the workflow of the clinical processes in an ICU better. The study was conducted in a medical ICU, and 35 data points were collected. The outcomes of this study will help nurse managers to improve the ICU nurses' workflows to minimize the delays and wasted time in care delivery.

**What has been accomplished on your project goals?**

- Workflow analysis was performed to identify a physical layout of the ICU

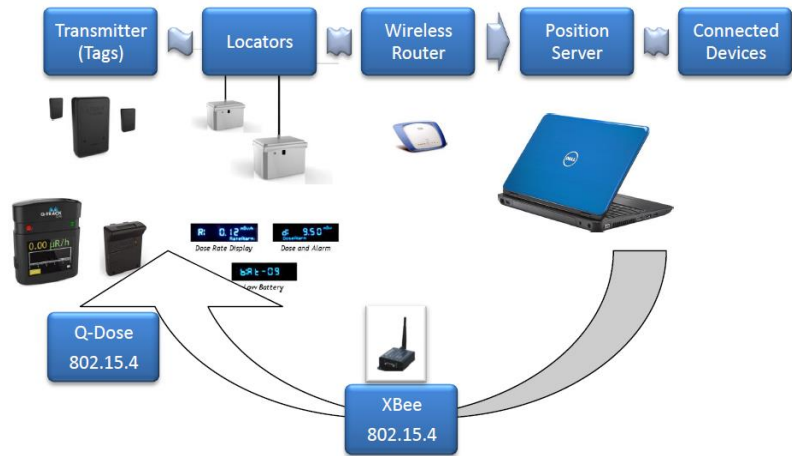
The study was conducted at the University Hospital, University of Missouri Health Care in Columbia, Missouri. There are 18 single patient rooms in the ICU. The reception desk is located in the middle of an ICU. The nurse-to-patient ratio can be 1:1, 1:2, or 1:3 depending on the patient's severity of illness. Nine to ten nurses work on the day shift (7:00 a.m. – 7:30 p.m.). The primary activities of ICU nurses are to assess and re-assess the clinical status of the patients, document their findings in the medical record, provide physical care and emotional support to patients, respond to routine, urgent and emergency situations, identify and communicate existing patients' problems with the physicians, prepare and administer medications to patients, and provide education to the patients and/or their families. There are several computer workstations to do patient medical data input, update their vital status, and handle system-generated warning signals. We collected 35 data points from 9 ICU nurses during their day shift. The nurses who volunteered to participate were all registered nurses and had at least one year of experience working in ICU.

- Data Collection

The NFER system was used to record the real-time location of nurses in an ICU. The system consists of six tracking servers to cover whole ICU area, a laptop computer with the tracking software, NFER sensors, which are tags carried by ICU nurses, and a router. The architecture of the NFER system is shown in **Figure 1**. The layout of the ICU with all calibration points and zones is shown in **Figure 2**.

The observation form (see **Figure 3**) was created to collect ICU nurse activity-level data. In the observation form, all nurse's activities were divided into five categories: 1) verbal report, 2) primary care (in-room activities), 3) peer support, 4) out-of-room activities, and 5) non-nursing activities. **Table 1** shows a detailed description of each category. In the form, a

single column represents 5 minutes time interval for any clinical activities. The comment column is used for taking notes of any important issues during the data collection. Each row contains the names of all activities that might happen in the ICU during the day shift. One page of the observation form can record one-hour data per nurse. Each observer wrote down a start time and end time of every activity that occurred during the day-shift.



**Figure 1:** NFER system Link Architecture



**Figure 2:** The layout of ICU with NFER calibration points

The observation was conducted one day per week by two observers. Every nurse was informed that they must wear an NFER tag for locating their position in an ICU. One observer shadowed two to three nurses together and monitored their activity data. To minimize the Hawthorne effect, the observer maintained a considerable distance from the participants and did not initiate any conversation with the nurses. To keep the patient privacy, the observers did not enter a patient room. The observer recorded the start time and end time of each task done by ICU nurses and made notes for any special events during the observation.

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University of Missouri Hospital ICU Department Collection Form (60 Minutes) Page 1																		
Start Time:		End Time:		Date:					Nurse:					Observer:				
No	Activity	0	5	10	15	20	25	30	35	40	45	50	55	Total	Comments			
<b>Verbal Reports</b>																		
V1	Start of Shift Report (Big Report)																	
V2	One-to-One Meeting (Nurse Handoff)																	
<b>Primary Care (In-Room)</b>																		
PC1	Initial Assessment(Vital)																	
PC2	Focused Assessment																	
PC3	Performing Procedure																	
PC4	Patient Care (Turning/Bathing/Etc)																	
PC5	Comforting/Teaching/Talking to Patients																	
PC6	Preparing/Administering Medications																	
PC7	Talking to Physician																	
PC8	Talking to Family																	
PC9	EMR Charting																	
PC10	Teaching Residents/Students																	
PC11	Using ASCOM Phone																	
PC12	Transport Patient/Prepare for Transport																	
PC13	Taking Notes About Patients (Brains)																	
PC14	Taking Lab Specimens																	
PC15	Stocking Room																	
PC16	Cleaning Room																	
PC17	Working on Monitors and Equipment																	
PC18	Attending/Participating in Clinical Rounds																	
PC19	Closed Curtain, Tasks Unknown																	
<b>Peer Support (In-Room)</b>																		
PS1	Assisting in Patient Care (Turning/Bathing/Etc)																	
PS2	Assisting in Procedure (Nurse-Led)																	
PS3	Assisting in Physician-Led Procedure																	
PS4	Closed Curtain, Tasks Unknown																	
<b>Out-Of-Room</b>																		
O1	Printing EKG Strips																	
O2	Using ASCOM or Table Telephones																	
O3	Talking with Physicians																	
O4	Talking with Other Healthcare Personnel																	
O5	Talking with Patients' Family																	
O6	Teaching Residents/Students																	
O7	Getting Supplies/Preparing for Procedures																	
O8	Staff Meeting (Morning Huddle)																	
O9	Washing Hands																	
O10	Getting/Preparing Medications																	
O11	EMR Charting																	
O12	Taking Notes About Patients (Brains)																	
O13	Transporting Lab Specimens																	
O14	Performing Unit Tasks																	
O15	Reviewing Paper Documents																	
<b>NVA Activities</b>																		
N1	NVA Conversation																	
N2	Waiting to Give Report to Nurse																	
N3	Waiting to Receive Report from Nurse																	
N4	Leave Unit (Restroom/Breaks)																	
N5	NVA Anything (Surfing Web/Phone/Etc)																	
N6	Lunch Break																	

Figure 3: Time Study Observation Form

**Table 1 – The Descriptions of Activity Categories**

<b>Category</b>	<b>Description</b>
<b>Verbal Report</b>	The first category is shift handoff , in which the off-going nurse provides the oncoming nurse with a detailed review of the important issues about the patient including their illness, clinical status, any events that occurred during the previous shift, and various measures which need to be undertaken for the betterment of the patients (V2: Nurse Handoff).
<b>Primary Care</b>	The second category contains all activities conducted in the patient rooms, including PC1: initial assessment, PC2: focused assessment, PC3: performing procedure, PC4: patient care, PC5: comforting/teaching/talking to patients, PC6: preparing/administering medications, PC7: talking to physician, PC8: talking to family, PC9: EMR charting, PC10: teaching residents/students, PC11: using ASCOM phone, PC12: transporting patient/prepare for transport, PC13: taking notes about patients, PC14: taking lab specimen, PC15: stocking room, PC16: cleaning room, PC17: working on monitors and equipment, PC18: attending/participating in clinical rounds, and PC19: closed curtain (tasks unknown).
<b>Peer Support</b>	The third category contains expected activities that the nurses support each other as able and as needed to provide patient care. Include PS1: assisting in patient care (turning/bathing/etc.), PS2: assisting in the procedure (nurse-led), PS3: assisting in the physician-led procedure, PS4: closed curtain in unassigned patient rooms (tasks unknown).
<b>Out-of-room</b>	The fourth category contains all activities related to the patient care, but nurses conducted them outside of the patient room (including O1: printing ECG strips, O2: using ASCOM or table telephones, O3: talking with physicians, O4: talking with other healthcare personnel, O5: talking with patients' family, O6: teaching residents/students, O7: getting supplies/preparing for procedure, O8: daily staff meeting (morning huddle), O9: washing hands, O10: getting/preparing medications, O11: EMR charting, O12: taking notes about patients, O13: transporting lab specimen, O14: performing unit tasks, and O15: reviewing paper documents).
<b>Non-nursing</b>	The fifth category is for miscellaneous tasks related to a managerial, social or personal nature. It includes personal breaks, social conversation, personal phone calls, and browsing websites. All activities that are not related to the patient care at all.

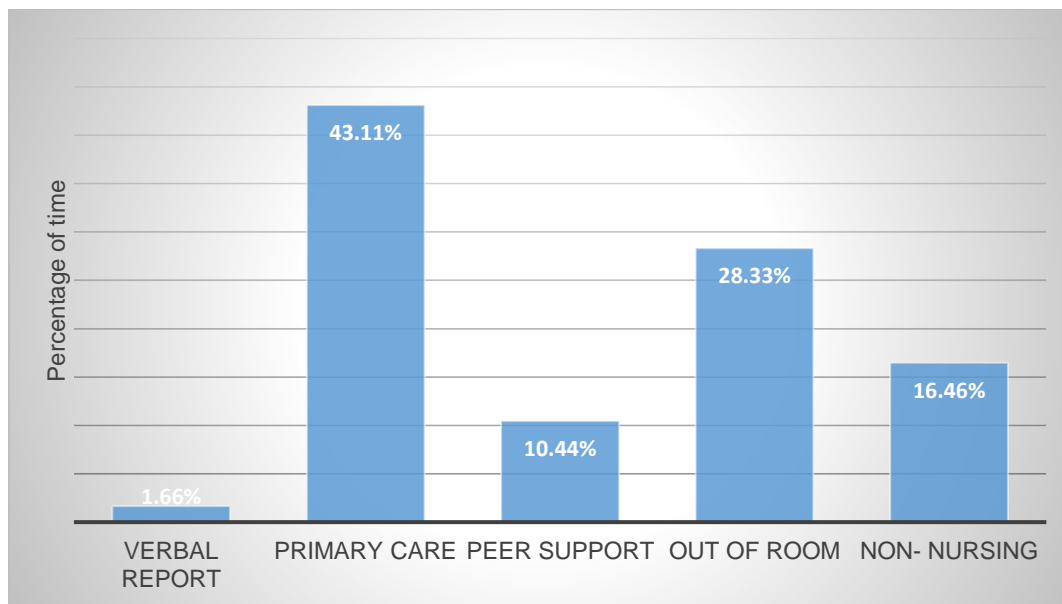
- **Data Analysis**

The observation data combined with the real-time location data from the NFER system. Based on the x-y coordination of each NFER tag, the data clearly showed nurses' location at the particular time. In addition, by filtering time stamp data, we can find a start time and the duration of nurse's movement. After that, a sequence diagram of each nurse data was created for a clear view of each clinical workflow during the shift. Then, the process time data from the sequence diagrams were summarized. We calculated the total length of the observation session, time spent on each activity per day, the average duration of each activity, each activity's time distribution, and the standard time for each activity.

- **Project Results**

Twelve observation sessions were observed from July to October 2016. In total, 35 data points were collected from 11 ICU nurses. The total observation time was 432 hours (25894 minutes) and the average time per observation day was 12.3 hours (740 minutes). Among these 11

nurses, 7 nurses have relatively low experience while 4 nurses have relatively high experience (threshold is 2-year experience). The time spent on different activities was then summarized with a mean and SD. The percentage of time that the subjects spent on different categories are shown in **Figure 4**. As seen from the figure, nurses spent 1.66% of their total time on the verbal report, 43.11% on primary care, 10.44% on peer support, 28.33% on out-of-room activities and 16.46% of the time on non-nursing activities. The summary of activity time devoted to each task per day is shown in **Table 2**.



**Figure 4:** The percentage of time devoted to each category of clinical task

**Table 2 –** The summary of process time spent on the activities

ID	Key clinical processes in ICU	Mean (minutes/event)	SD	95% CI
V2	One-to-One Meeting (Nurse Handoff in Nurse station)	9.479	6.953	(8.487,10.470)
PC13	Take Notes about Patients (In-room)	7.5	7.78	(1.59,13.41)
O12	Take Notes about Patients (Out-of-room)	2.769	4.053	(1.131,4.407)
PC10	Teach Residents/Students (In-room)	3.022	2.896	(1.777,4.267)
O6	Teach Residents/Students (Out-of-room)	3.406	2.894	(1.930,4.883)
PC9	EMR Charting	2.425	3.086	(2.359, 2.976)
PC18	Attending/Participating in Clinical Rounds	7.563	5.404	(6.518, 8.607)
PC12	Transport Patient/Prepare for Transport	12.95	19.44	(11.13, 14.78)
O7	Getting Supplies/Preparing for Procedures	1.6154	0.9928	(1.0839, 2.1469)
PC15	Stocking Room	3.556	3.367	(1.948, 5.163)
PC16	Cleaning Room	4.283	4.319	(3.051, 5.514)
PC5	Comforting/Teaching/Talking to Patients	3.253	3.074	(1.855, 3.164)

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V2+PC1	One-to-One Meeting (Nurse Handoff in Patient Room)	9.898	5.803	(8.811, 10.986)
PC1	Initial Assessment(Vital)	2.425	3.454	(2.961, 5.914)
PC2	Focused Assessment	5.115	1.973	(1.491, 3.359)
PC3	Performing Procedure	3.640	4.955	(4.358, 5.871)
PC4	Patient Care (Turning/Bathing/Etc)	4.650	3.900	(3.226, 4.053)
PC4(+P C2)	Patient Care (+Focused Assessment)	2.509	6.621	(4.033, 5.268)
O10	Getting/Preparing Medications	1.5933	0.9580	(1.1110, 2.0756)
PC6	Preparing/Administering Medications	2.375	2.549	(2.728, 3.778)
PC17	Working on Monitors and Equipment	2.830	3.194	(2.111, 3.549)
PC14	Taking Lab Specimens	4.077	2.182	(3.041, 5.113)
O13	Transporting Lab Specimens	1.746	0.939	(0.658, 2.833)
PC19	Closed Curtain, Tasks Unknown			
PC1	Initial Assessment(Vital)	6.70	7.39	(4.06, 9.34)
PC2	Focused Assessment	6.371	5.554	(5.373, 7.370)
PC3/PC 4	Performing Procedure/Patient Care	7.554	8.520	(6.982, 8.126)
O8	Staff Meeting (Morning Huddle)	4.963	3.082	(3.355, 6.571)
O11	EMR Charting	4.718	4.701	(4.357, 5.079)
O1	Printing EKG Strips	2.056	1.474	(0.087, 4.025)
O9	Washing Hands	1.1905	0.5639	(0.1380, 2.2429)
O14	Performing Unit Tasks	2.958	3.096	(2.312, 3.604)
O15	Reviewing Paper Documents	2.774	2.557	(1.713, 3.835)
O16	Unknown Activity	4.952	4.633	(3.663, 6.241)
PS1	Assisting in Patient Care (Turning/Bathing/Etc.)	4.921	5.231	(4.452, 5.390)
PS2	Assisting in Procedure (Nurse-Led)	6.82	7.10	(5.56, 8.08)
PS3	Assisting in Physician-Led Procedure	10.67	10.70	(9.06, 12.27)
PS1	Assisting in Patient Care (Turning/Bathing/Etc.)	4.921	5.231	(4.452, 5.390)
PC11	Using ASCOM Phone	2.000	2.000	(0.567, 3.433)
O2	Using ASCOM or Table Telephones	2.491	2.409	(1.945, 3.038)
PC7	Talking to Physician	2.671	1.644	(1.054, 3.696)
O3	Talking with Physicians	1.963	1.645	(1.244, 2.682)
O4	Talking with Other Healthcare Personnel	2.776	2.807	(2.472, 3.080)
PC8	Talking to Family	2.668	2.692	(1.765, 3.577)
O5	Talking with Patients' Family	2.875	2.232	(1.170, 4.580)
N1	NVA Conversation	4.526	4.687	(4.130, 5.283)
N2	Waiting to Give Report to Nurse	1.750	0.500	(-2.437, 5.937)
N3	Waiting to Receive Report from Nurse	4.50	3.11	(0.31, 8.69)
N4	Leave Unit (Restroom/Breaks)	4.843	5.591	(4.106, 5.710)
N5	NVA Anything (Surfing Web/Phone/Etc.)	4.440	5.113	(4.101, 4.996)
N6	Lunch Time	29.771	5.724	(28.08, 31.04)

**What remains to be accomplished?**

In this project, we used the NFER system which could provide an accurate location in the complicated non-line of sight working environment with a high level of proximity detection. Our results show that the NFER system could overcome the limitations of the traditional time study methods and make us possible to record all nurses' location data automatically. Moreover, the

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NFER system can help us to obtain a comprehensive picture of nurses' workflow. Although the findings from this study advanced our understanding of ICU nurse's working hours in detail, there are a couple of limitations of the study. First, all studied nurses were from one specialty ICU and only the day-shift nurses have been monitored. Second, the sample size was smaller than other studies. We only used 35 data points to calculate the process time of ICU nurse's clinical activities. Third, the time spent on primary care done by the nurses who did not wear the NFER tag was not collected during the study. Also, it was impossible to observe the nurse's direct care time when he or she closed a room curtain to protect patient privacy. For the future project, we should include night-shift nurses to draw the complete picture of nurse's workflow in intensive care nursing. Also, we should create workflow sequence diagrams for ICU nurses by using the data from the observation the NFER system to analyze the actual nursing workload in an ICU.

### Budget/ Expenditures

Description	Expense	Balance
IIF		\$24,990
Payroll – undergraduate researchers	\$1,070.00	\$23,920.00
Locators (QT-552 wired w/power supplies)	\$8,250.00	\$15,670.00
Tags (QT-640)	\$7,740.00	\$7,930.00
Tag Chargers (QT-654v2)	\$1,035.00	\$6,895.00
Tracking Software w/NFER License	\$2,000.00	\$4,895.00
Tracking Server	\$2,365.00	\$2,530.00
Installation	\$2,000	\$530.00
Shipping	\$120	\$410.00
Transport Case	\$330.68	\$79.32
Balance		\$79.32