Proactive software solutions to the Healthcare Associated Infection problem

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***Abstract*—Healthcare Associated Infections (HAI) are a top concern for healthcare administrators globally due to the cost of preventing HAIs as well as the cost associated with caring for patients whom have acquired an infection while in care. Throughout this paper we present statistics demonstrating how HAIs affect patients and the healthcare industry. We attempt to display the leading causes of HAIs as well as how technology is being used to prevent HAIs. Finally, based on survey results and literature reviews, we finalize our stand regarding the issue, what is lacking and what we can help to fill the gap using software technologies.**

***Index Terms*—Healthcare associated infection, clinical operation issues, electronic health record, EHR, real time, infection preventionist, precision tracking, threat map, data analytic, Google Trends.**

I. Introduction

In todays society its hard to find common aspects of life that affect everyone. However, that is not the case when speaking about healthcare. Whether you are a child or a senior, healthcare dictates many aspects of peoples daily lives. Unfortunately, the high monetary cost of healthcare and a persons socio-economic standing usually correlate to the quality of healthcare people receive. As medical advances increasing the lifespan of the aging population, we can assume that the cost of healthcare will continue to rise with tax payers taking the brunt of the increased cost.

In an attempt to decrease healthcare cost, this paper aims to analyze Healthcare Associated Infections (HAI) which is a top concern for healthcare administrators and is considered one of the leading expenses within the healthcare system. According to the Center for Disease Control (CDC), HAIs are infections that patients acquire during the course of receiving treatment for other condition within a healthcare setting. However, HAIs are not limited to patients, but can also include healthcare staff that acquires an infection while caring for an infected patient. Recently, HAIs have gained increased attention due to high profile cases such as the Ebola outbreak in 2014 which resulted in two nurses contracting the Ebola virus while giving treatment to an Ebola patient in Texas. Other cases of HAIs include antibiotic resistant super-bugs such as MRSA which has become increasingly common in healthcare settings. The goal of this paper is to provide the current landscape of Healthcare Associated Infections (HAI), identify the main causes of HAIs and the prevention methods currently practice within the healthcare community. Specifically, we examine how technology and software is used as a HAIs prevention tool and how might the adaptation of data as a surveillance system reduce the number of HAIs. We attempt to analyze statistics surrounding HAI to highlight the prevalence of the problem as well as identify how HAIs contribute to the over cost of our increasing healthcare coverage. We will provide data from surveys we conducted which will provide insights from personnel within the healthcare community. Lastly, we conclude with a short literature review of HAIs and briefly begin to discuss potential software solution that attempt to reduce the prevalence of HAIs.

II. Issue Research

A. Statistics about HAI

In the cited book, Critical Issues in Healthcare Environments [1], a study was conducted to identify and describe critical issues in hospital, ambulatory, and long-term care settings hospital environments. Participants in the survey of this project include 639 individuals, of which 443 addressed the hospital setting, 103 addressed the ambulatory care setting, and 93 addressed the long-term care setting. Problems identified in this project indicate that hospital acquired infection (HAI) is the top issue in hospital as displayed in Fig. 1.

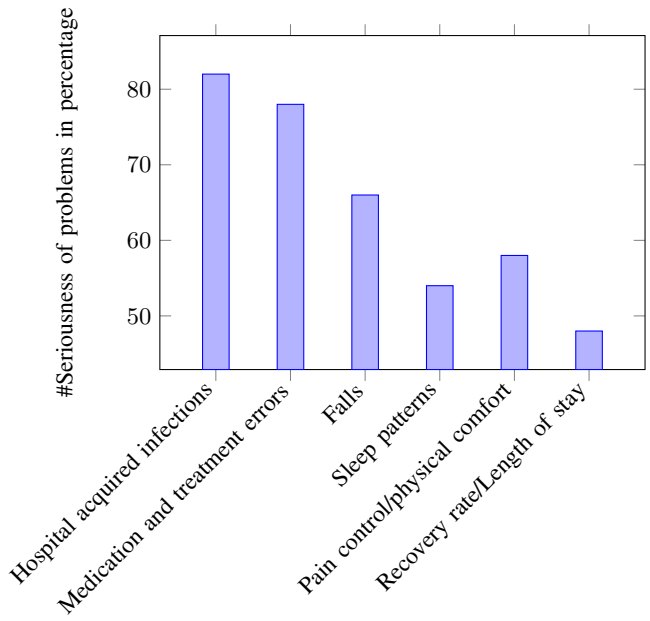

Fig. 1. Top Issues In Hospital Setting

In ambulatory environment as in Fig. 2, communication and information are ranked as top issue which indicates that being able to access health-care information is a primary concern of patients.

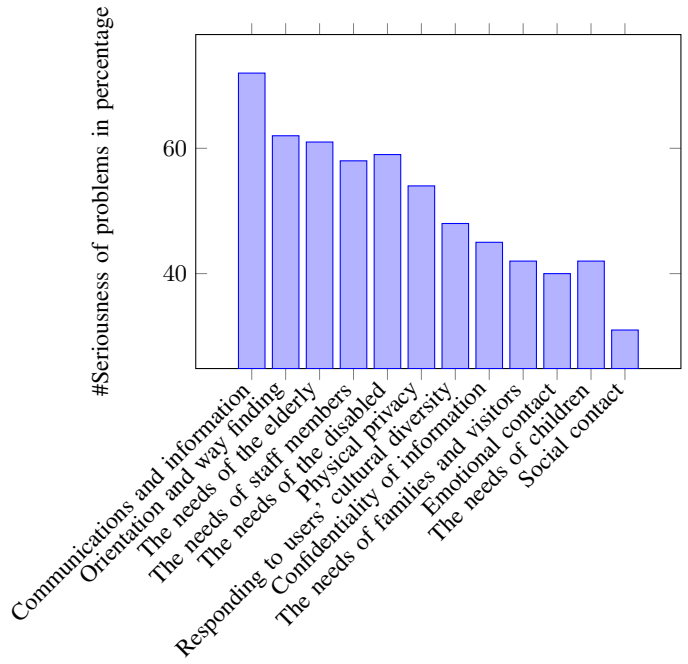

Fig. 2. Top Issues In Ambulatory Setting

Fig. 3 also indicates that many people concern the communication and information issue in long term care environment. To sum up with Fig. 4, faculty acquired infections as well as medication and

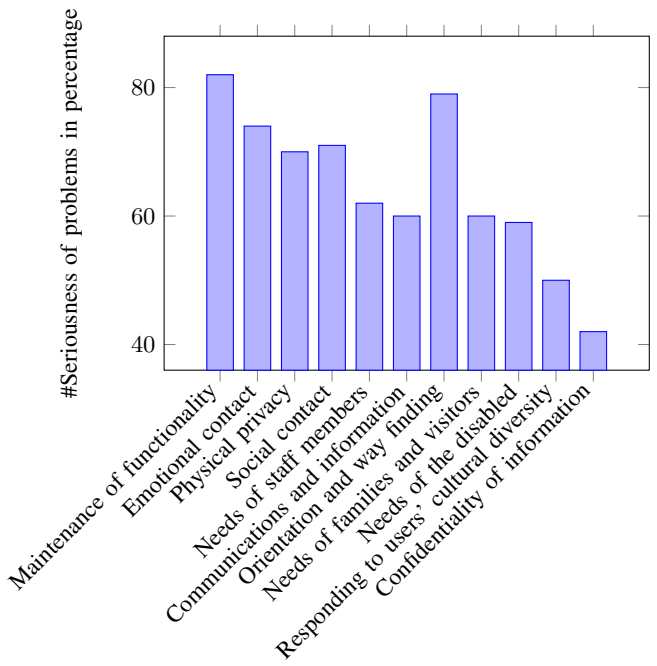

Fig. 3. Top Issues In Long Term Care Setting

treatment errors could both be categorized to HAI issues and which all obtain almost or more than 50 percent concerns. In Fig. 5 more detailed issues are listed and many of them may be direct or indirect related to HAI.

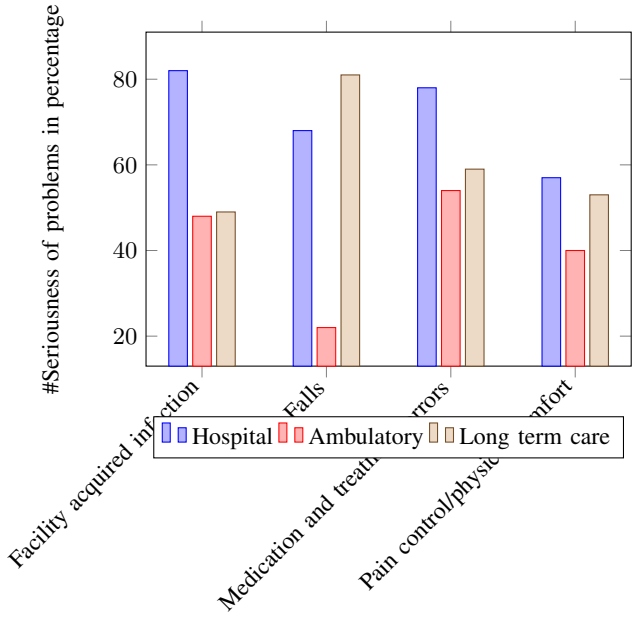

Fig. 4. Comparison among ambulatory, hospital and long term care environments

We also found some statistics data about HAI on the website of the Centers for Diseases Control and Prevention (CDC) [2] as well as from study conducted by CDC.

- About one in 25 hospital patients has at least one healthcare associated infection on any given day
- An estimated 722,000 HAIs in U.S. acute care hospitals in 2011
- About 75,000 patients with HAIs died during their hospitalizations in 2011
- More than half of all HAIs occurred outside of the intensive care unit
- When healthcare staffs are aware of infection problems and take specific steps to prevent them, rates of some targeted HAIs can decrease by more than 70 percent

Although above information suggests that being aware of infections significantly help to reduce HAI, humans should not be assumed that will never make mistakes, and that thought brought out our motivations for improving HAI with technologies.

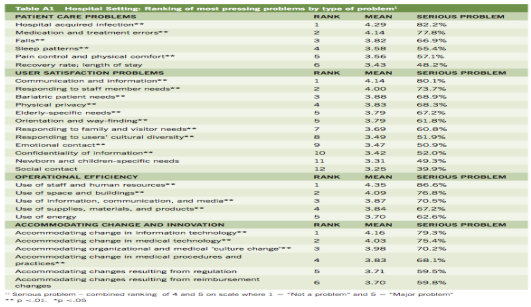

Table A1 Hospital Setting: Ranking of most pressing problems by type of problem[1]

PATIENT CARE PROBLEMS	RANK	MEAN	SERIOUS PROBLEM
Hospital acquired infection**	1	4.29	82.2%
Medication and treatment errors**	2	4.14	77.8%
Falls**	3	3.82	66.9%
Sleep patterns**	4	3.58	55.4%
Pain control and physical comfort**	5	3.56	57.1%
Recovery rate; length of stay	6	3.43	48.2%
USER SATISFACTION PROBLEMS	**RANK**	**MEAN**	**SERIOUS PROBLEM**
Communication and information**	1	4.14	80.1%
Responding to staff member needs**	2	4.00	73.7%
Bariatric patient needs**	3	3.88	68.9%
Physical privacy**	4	3.83	68.3%
Elderly-specific needs**	5	3.79	67.2%
Orientation and way-finding**	5	3.79	61.8%
Responding to family and visitor needs**	7	3.69	60.8%
Responding to users' cultural diversity**	8	3.49	51.9%
Emotional contact**	9	3.47	50.9%
Confidentiality of information**	10	3.42	52.0%
Newborn and children-specific needs	11	3.31	49.3%
Social contact	12	3.25	39.9%
OPERATIONAL EFFICIENCY	**RANK**	**MEAN**	**SERIOUS PROBLEM**
Use of staff and human resources**	1	4.35	86.6%
Use of space and buildings**	2	4.09	76.8%
Use of information, communication, and media**	3	3.87	70.5%
Use of supplies, materials, and products**	4	3.84	67.2%
Use of energy	5	3.70	62.6%
ACCOMMODATING CHANGE AND INNOVATION	**RANK**	**MEAN**	**SERIOUS PROBLEM**
Accommodating change in information technology**	1	4.16	79.3%
Accommodating change in medical technology**	2	4.03	75.4%
Accommodating organizational and medical 'culture change**'	3	3.98	70.2%
Accommodating change in medical procedures and practices**	4	3.83	68.1%
Accommodating changes resulting from regulation	5	3.71	59.5%
Accommodating changes resulting from reimbursement changes	6	3.70	59.8%

[1] Serious problem = combined ranking of 4 and 5 on scale where 1 = "Not a problem" and 5 = "Major problem"
** p <.01; * p <.05

Fig. 5. Summary of Patient Concerned Issues

B. User studies

1) Methods

We used a combination of conducting paid surveys, performing phone interviews and reading online forum/social group posts. We started with a short survey touching the surface of the issue. Based on the responses (30), we schedule interviews with healthcare executives who have more than 20 years of professional experience at all levels. After that, we look up responses from other healthcare professionals regarding a certain topics discovered during the interview(s). We then study the collected data in conjunction with literature findings, and start another cycle of survey-interview-forum check-literature reading if necessary. There were two cycles performed at the time of this paper. All of our surveys were designed based on the world class Qualtrics platform and distributed via Amazon's Mechanical Turk market place. For quality assurance, we employed response time tracking, captcha and attention check questions within the survey, manual human cross check before the removal of invalid responses.

2) Collected results

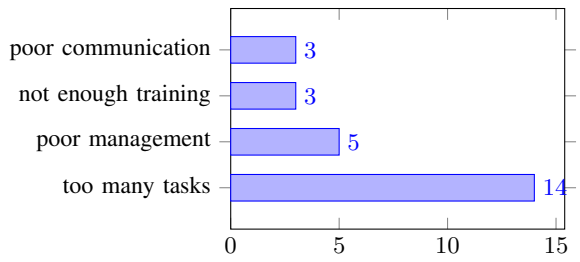

Fig. 6. Survey: Top reasons for mistakes to happen

Most participants demonstrated low confidence in existing surveillance program (49% detractor and 49% passive when were asked about the effectiveness of surveillance program.)

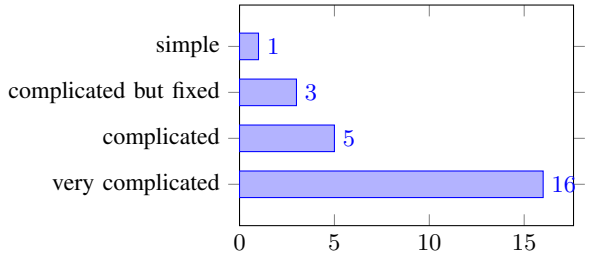

Fig. 7. Survey: Complexity of a nurse's workflow

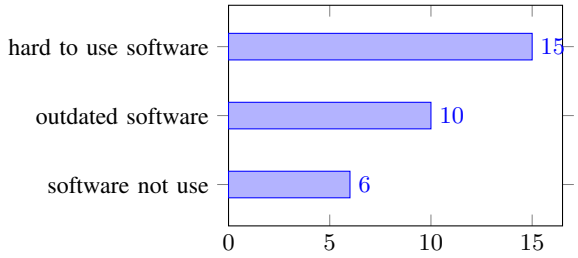

Fig. 8. Survey: The use of software to prevent H.A.I

Top issues with surveillance program are (most significant first):

- Lack of training on the surveillance system
- Taking too much time to input/update data into the system
- Difficulties with understanding the system

More than 60% of survey participants want software that can help them track their tasks and improve general situation awareness. Detailed reports of our surveys can be viewed at http://tiny.cc/tiyoiy (first survey), and at http://tiny.cc/sur2 (the second survey with passcode "whitewolf") From our interviews with healthcare executives, all of them agreed that healthcare associated infections have always been an issue. Executives are also aware that a nurse's workflow is very dynamic and complicated as Fig. 7 shows. On top of that, nurses are categorized into different types receiving different levels of training which can cause issues when their workflows crossing each other (as in the case of an emergency complication.)

3) Analysis

It appears that HAI happens due to real life/real time complications which do not completely belong to any specific trained procedures or planned ahead situations. For example, one of the most effective ways to prevent HAI is sanitizing the care givers' hands properly. We believe most care givers are very well trained on that procedure yet from our survey results, it is listed as one of the most common operational mistakes. Surveys also shows that most nurses do not feel the positive impacts of an HAI surveillance system on their daily jobs. In many cases, the software used takes too long for data to be input and/or too complicated to use (Fig. 7). These two factors when combined raised a question of why there is such a big gap in the way HAI surveillance system was designed and the actual complicated extremely dynamic reality nurses have to deal with. We found the answer to this question and discuss it in the following literature review section. Interview sessions and social group discussion readings also suggest that there is a huge cultural issue in dealing with HAI prevention. For example, in anonymous discussions of potential HAI cases between nurses online, "do not self report" is a common advice. On a larger scale at higher levels, executives also do not want to admit there is a big HAI issue going on. Even when the facts are undeniable, they obviously do not want to publish or share such information with anyone (if they do not have to). We believe this is the major issue in collecting data, interpreting data and responding to findings which will also be discussed further in the literature review section.

III. Literature Review

To understand the issues surrounding HAIs we researched scholarly articles and analyzed data which helped us confirm our initial assessment of the problem and gave us insights to how we can formulate possible solutions to reduce HAIs. Our initial research found that the effects of HAIs are far more serious than we first assumed. According to one study, central-line associated bloodstream infections (CLABSI) transmitted during a surgical procedure have a mortality rate of 35 percent [3]. Not only are HAIs deadly, causing an estimated 99,000 deaths in the U.S. a year, but they are extremely costly, averaging a cost of 33 billion dollars each year in the U.S. [3]. From our review we found that one of the leading causes of HAIs is due to increased use of invasive devices [3]. An invasive device is categorized as any device that penetrates inside a patients body; this makes sense that invasive devices have this effect but in reality an invasive device is only the medium that spreads infections, and is not necessarily the source of the infection. Recently billion dollar investments into prevention studies and application aimed at reducing HAIs have had positive results. However, countries with low economic standings cannot afford costly HAI prevention studies and application. It has been shown that a counties socio-economic standing is correlated with HAI rates [3]. Wealthier countries have lower HAI rates than poorer countries.

In [4], Ducel and his coworkers defined nosocomial infections and feasible solutions. However, those solutions are guidelines and HAIs may occur with neglection or human errors. To improve compliance with hand hygiene, a hospital-wide programme, with special emphasis on bedside, alcohol-based hand disinfection([5]) was implemented during routine patient care in a teaching hospital in Geneva, Switzerland and ended up with a progressive increasing in compliance by 18 percent. Although this approach seems practical, there's no guarantee that the instructions or guidelines will be definitely executed.

With data mining techniques, the scattered but massive data on the Internet now become a powerful tool to make predictions. According to [6], although not in exact occurrences, Google Flu Trends data showed a good match in trend patterns and provide a timely, inexpensive data source to develop an alarm system for outbreaks of influenza. In our project, we aim to extend the range of trends to cover as more as infectious diseases.

In 1986, researchers at LDS Hospital in Salt Lake City, Utah, published a groud breaking method of identifying possible HAIs based on lab results [7]. Since then, the most common steps to prevent HAI is first to gather as much data as possible. Then an infection preventionist will review the data and come up with conclusions and/or recommendations for changes. Even with extensive use of Electronic Health Records, gathering data is still a great challenge nowadays. One of the issues is data resolution. For example, regarding central venous catheter (CVC) line, most systems implement a check box (representing "yes" or "no") for the presence of CVC. Such system does not track how many lines were used and the duration of use. Some modern devices were network enabled and can automatically report such data but not all healthcare facilities can afford or want to upgrade their devices.For another example, when reporting attempted procedures, it is common that

a procedure code is used rather than describing in details what had happened. Another issue is data availability interm of data integration between different systems. The same procedure code may mean differently in different systems or may represent procedures that are not completely the same. Due to resource limitations (staffs, software, hardware, time), some places will not digitalize certain records (such as bedside logs) and when other places want to access such data, there is a considerable delay time. In order to compensate for errors during the complicated process of data gathering, there are two types of validations : internal validation and external validation in which it is required that the same data that was made available for internal validation must also be made available for external validation. Within each category, there are denominator validation and numerator validation. An electronic surveillance system usually will have to generate a report per specified cycle and such report will be compared with manual surveillance results. For example, a device usesage electronic report will be compared with a manual device count.

It is of no doubt that there are steady advances in making fully automated electronic surveillance a reality. However, our team noticed that most surveillance efforts only focus on deciding whether HAI has already happened or not. It shows in the way data collection was engineered around lab results and device logs. While it makes sense to rely on concrete data especially when some HAI cases can lead to legal complications, it does not make sense to wait for those data to arrive and not treat HAI soner. For example, it may take a while for an infection to get to a level detectable by lab tests and it may take a while to have some lab test results. Our team believes that the best approach to HAI is taking a pro-active stand - identify HAI as quick as possible and come up with remedy steps as fast as possible. In order to do that, we need to find ways to get and analyze real-time data. The next paper mentions the importance of gathering contextual data and we think it is the key for a pro-active strategy when dealing with HAI.

In 2016 [8], C. Hooker and his team used the common example of keeping hand hygiene to reveal and emphasize the limitations of current surveillance system. One of the key argument is about how boundaries of spaces are defined. When we look at healthcare designs whether it is architectural designs or procedural/protocol designs etc., it is obvious that the designers have tried to set boundaries, limiting complications or collisions as much as possible. The argument is that no matter how well the designs are, the human behaviors dictate the HAI outcomes. For example, an experienced nurse with her RFID badge can enter a well sanitized secure room. She was well trained and the procedure is routine but for some reasons, she made a mistake and HAI occurred. In contrast, a medical school student shadowing the nurse was there in the same room but he did not touch or do anything and hence removed himself from any potential HAI incident. The importance of human factor becomes more important when there are endless complications regarding zones and boundaries in real life situations. In one case, HAI happened because a nurse let medical equipment touch a patient's arm while treating the other arm. The nurse was in the assumption that the whole body was under a disease and it would not cause more problem when a device used for treating this arm touched the other arm. It turned out that there was another problem growing on the skin of the other arm. In another case, the cause of HAI was due to the mis-handling of medical tapes. A roll of medical tape was placed on a patient's bed during a procedure or was touched by different nurses. The tape problem was corrected by implementating single-use medical tapes. "...their (the boundaries) integrity is primarily held in the mind, and maintained or breached through (in)attention and behaviour." The interesting thing is C. Hooker and the team [8] did not rely on device electronic logs or lab results but rather using video-reflexive ethnography (VRE) and actual human observations to study and identify the causes of HAI during the entire 3 years of their research.

IV. Proposed solutions

Based on our findings, we recommend the following solutions. 1. We need to change the culture of how we perceive and react to HAI. Instead of confirming HAI, we need to focus more on predicting HAI. With prediction and early prevention, the chance of being investigated and/or being sued is much lesser than the case of a confirmed HAI. With that as an incentive, we believe more people will be more willing to participate in the data colection process. In a long run, it will also increase the speed of patient flow resulting in higher revenue for the institution and lesser work load for nurses.

2. Instead of statistical data, we need to focus more on gathering contextual data. We believe it is not harder to design a system that can identify abnormalities in contextual data when compared to a system designed for statistical data. Understand the context of an incident can also be very beneficial to many stakeholders. The policy makers will be able to make adjustments to policies and work flows. Helpful contextual data may also help nursees to defend themselves in court cases. 3. We need to focus on real-time data collection, data sharing and data processing. Each and every second, there are million of usable data floating around both inside and outside an institution. What if a police's incident database can help with the positioning of ambulances for future cases? What if a twitter trend can help with forecasting a problem?

V. Conclusion

As we have shown, HAI is a problem worth solving. HAI causes increased healthcare cost for the patients and is associated to many unnecessary deaths each year. Current solutions have yet to provide significant results and have become a nuisance to the healthcare workers responsible for their implementation. The most promising solution involves surveillance programs which are intended to monitor the environment, specifically data meant to identify potential triggers of HAI. Unfortunately, these surveillance programs are time intensive and as stated above are sometimes too complicated for worker to understand. As we proposed our solutions in section IV, it is necessary to restate that specific impliementation of solutions will need to benefit as many stakeholders as possible, especially nurses. We need to address the hectic work shift of a nurse. Solutions should revolve around making nurses workflows easier to manage and promote the culture of early reporting/prevention.

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