

Patient Safety Regarding Medical Devices at ICUs in Bangladesh

TONIMA AFROZE
MIA ISAKSSON PALMQVIST



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and Health**

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Patientsäkerhet med avseende på
medicinteknisk utrustning på
intensivvårdsavdelningar i Bangladesh

TONIMA AFROZE
MIA ISAKSSON PALMQVIST

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Supervisor at KTH: Mannan Mridha
Examiner: Lars-Gösta Hellström
School of Technology and Health
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Royal Institute of Technology
KTH STH
SE-141 86 Flemingsberg, Sweden
<http://www.kth.se/sth>

Abstract

Accidents related to medical devices are a worldwide problem and result in many deaths each year. It affects patients, relatives, health care workers and society. Due to the complexity of intensive care units (ICUs), such accidents lead to particularly serious consequences. The aim of this thesis was to identify patient safety aspects at ICUs in public and private hospitals in Bangladesh, in order to provide a basis for improving the quality of performance of devices as well as personnel, care and cost effectiveness. The objectives were to

- a) compare the conditions of medical devices at ICUs in private and public hospitals,
- b) increase understanding of errors, risks and accidents related to medical devices,
- c) study reporting systems and communication between staff at ICUs and
- d) find ways to minimize hazards related to medical equipment to ensure effective and safe use of devices.

Data was collected through interviews during field visits to six hospitals in Dhaka, Bangladesh. Interviews were held with the chiefs of the ICUs, physicians, nurses and technicians.

It was noticed that the admission fees to the public hospitals were lower and had more limited resources. Differences between public and private hospitals could be seen in the aspects of finance, the existence of a Biomedical Engineering Department, maintenance and calibration of medical equipment, further education of staff, working environment and infection control. The reporting systems for adverse events and communication about patients' conditions between coworkers were weak at all hospitals. The procurement process was lengthy at all hospitals. Access to disposable items was limited at several hospitals.

The lower admission fee at the government hospitals results in the patients of these hospitals often having a lower income and status, thus less inclined to be critical of the received care.

A number of suggestions have been proposed in order to improve the work in the ICU. These include

- a) following up rules made by the authorities to ensure they are implemented at each hospital,
- b) increasing documentation of malfunctioning devices and adverse events,
- c) nurses and physicians taking part in the procurement process,
- d) establishing a Biomedical Engineering Department at all hospitals,
- e) organizing workshops for health care workers,
- f) developing biomedical products adapted for multiple time use and with less need for calibration,
- g) providing more education for health care workers in infection control, management of specific devices, solutions to common technical problems, patient safety and user safety, for example using Information and Communication Technology tools (audio and audiovisual material) and discussion platforms as well as
- h) constructing an internet forum for consultation on the abovementioned subjects for technicians.

Key words: patient safety, Bangladesh, Intensive care units, ICUs, private hospitals, public hospitals, medical devices.

Sammanfattning

Olyckor relaterade till medicinteknisk utrustning är ett globalt problem som leder till många dödsfall varje år. Det påverkar patienter, anhöriga, sjukvårdspersonal och samhället. Den komplexa miljön på intensivvårdsavdelningar gör att olyckorna leder till allvarliga konsekvenser. Uppsatsen syftade till att identifiera patientsäkerhetsaspekter på intensivvårdsavdelningar i Bangladesh för att skapa en grund för prestandaförbättring, både gällande utrustning och gällande personal. Det ska också öka vård- och konstandseffektiviteten. Målet uppnåddes genom att

- a) jämföra användandemiljön för medicinteknisk utrustning på intensivvårdsavdelningar på statliga och privata sjukhus,
- b) öka förståelsen för fel, risker och olyckor relaterade till medicinteknisk utrustning,
- c) studera rapporteringssystem samt kommunikation mellan personal på intensivvårdsavdelningar och
- d) hitta sätt att minimera faror relaterade till medicinteknisk utrustning för att försäkra en effektiv och säker användning av utrustningen.

Data samlades in genom intervjuer under en fältstudie på sex sjukhus i Dhaka, Bangladesh. Intervjuer hölls med cheferna på intensivvårdsavdelningarna, läkare, sjuksköterskor och tekniker.

Det upptäcktes att patientavgiften på de statliga sjukhusen var lägre och resurserna var mer begränsade. Skillnader mellan statliga och privata sjukhus kunde ses inom ekonomiska resurser, förekomsten av medicintekniskavdelning, underhåll och kalibrering av medicinteknisk utrustning, vidareutbildning av personal, arbetsmiljö och infektionskontroll. Rapporteringssystemen för olyckor samt kommunikationen om patienters tillstånd mellan medarbetare var bristfällig på alla sjukhus. Upphandlingsprocesserna av ny medicintekniskutrustning var lång på alla sjukhus. Tillgången på engångsartiklar var begränsad på flera utav sjukhusen.

Den lägre avgiften på de statliga sjukhusen resulterar i att patienterna på dessa sjukhus ofta har lägre inkomst samt status i samhället och är därför mindre benägna att vara kritiska till den mottagna vården.

Ett antal ändringar föreslogs för att förbättra arbetet på intensivvårdsavdelningarna. Dessa inkluderar att

- a) följa upp de av myndigheterna satta reglerna för att försäkra att de är implementerade på varje sjukhus,
- b) öka dokumentationen av icke fungerande utrustning tillika olyckor,
- c) sjuksköterskor och läkare skall delta i upphandlingsprocesserna,
- d) starta medicintekniska avdelningar på alla sjukhus,
- e) organisera workshops för vårdpersonal,
- f) utveckla medicintekniska produkter som är anpassade för att användas flera gånger och som behöver kalibreras mer sällan,
- g) ge mer utbildning till sjukvårdspersonal om infektionskontroll, hantering av specifika maskiner, lösningar till vanligt förekommande tekniska problem, patientsäkerhet och användarsäkerhet till exempel genom att använda information- och kommunikationsteknik-verktyg (audio och audiovisuellt material) och diskussionsplattformar samt
- h) konstruera ett internetforum där tekniker kan få konsultation angående ovannämnda ämnen.

Nyckelord: patient safety, Bangladesh, intensive care units, ICUs, private hospitals, public hospitals, medical devices.



This study has been carried out within the framework of the Minor Field Studies Scholarship Programme, MFS, which is funded by the Swedish International Development Cooperation Agency, Sida.

The MFS Scholarship Programme offers Swedish university students an opportunity to carry out two months' field work, usually the student's final degree project, in a country in Africa, Asia or Latin America. The results of the work are presented in an MFS report which is also the student's Master of Science Thesis. Minor Field Studies are primarily conducted within subject areas of importance from a development perspective and in a country where Swedish international cooperation is ongoing.

The main purpose of the MFS Programme is to enhance Swedish university students' knowledge and understanding of these countries and their problems and opportunities. MFS should provide the student with initial experience of conditions in such a country. The overall goals are to widen the Swedish human resources cadre for engagement in international development cooperation as well as to promote scientific exchange between universities, research institutes and similar authorities as well as NGOs in developing countries and in Sweden.

The International Relations Office at KTH the Royal Institute of Technology, Stockholm, Sweden, administers the MFS Programme within engineering and applied natural sciences.

Lennart Johansson
Programme Officer
MFS Programme, KTH International Relations Office

Preface

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Tonima Afroze
Mia Isaksson Palmqvist

KTH STH

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¹ Bangabandhu Sheikh Mujibur Medical University

² Dhaka Medical College and Hospital

³ National Institute of Cardiovascular Diseases

⁴ Bangladesh Institute of Research and Rehabilitation for Diabetes

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1 Introduction

The intensive care unit (ICU) is one of the most complex wards at a hospital, where patients in life threatening conditions are treated. Striving for greater patient safety at ICUs, through handling of medical equipment, infection control and other methods will lead to fewer injuries and deaths as a result of care related causes. It will also greatly increase cost effectiveness, which favors the patient and patient's family, the hospital and society.

The need for safer and more effective ICUs is particularly important in low-income countries such as Bangladesh, where resources are limited. This thesis is based on a study of ICUs in Dhaka, Bangladesh. There is a difference in quality of care and the income of the admitted patients at private and public hospitals in Bangladesh. This study compares ICUs at private and public hospitals in Bangladesh. The terms "public hospitals" and "government hospitals" are used interchangeably throughout this thesis.

2 Aims and Objectives

The aim of this thesis was to identify patient safety aspects at ICUs in public and private hospitals in Bangladesh, in order to provide a basis for improving the quality of performance of devices as well as ICU personnel, care and cost effectiveness. The objectives were to

- a) compare the conditions of medical devices at ICUs in private and public hospitals,
- b) increase understanding of errors, risks and accidents related to medical devices,
- c) study reporting systems and communication between staff at ICUs and
- d) find ways to minimize hazards related to medical equipment to ensure effective and safe use of devices.

3 Background

Accidents related to medical devices are common and impact not only the patient, but also relatives and health care providers. It reduces able workforce and is hence costly for the society at large. Hazards most commonly derive from failure in design, organization and operational system at the Intensive Care Unit (ICU), rather than device failure (1). The large human toll together with the high financial toll puts the medical errors in the top rank of urgent, widespread public problems.

There are 4 hospital beds per 10 000 persons in Bangladesh (2). Further, Bangladesh has a population of 161,083,804 (July 2012), of which 14.251 million live in Dhaka. 31.5 % live on less than 1 US dollar a day (3).

3.1 Health care in Low-Income Countries

The subject of patient safety is establishing itself in the research domain. Numerous studies on different aspects of patient safety have been performed in high-income countries but few have been carried out in low-income countries like Bangladesh. In order to address the existing problems the current situation must be documented.

Out of 15 548 patient records reviewed in a group of low-income countries (in Africa and the Middle East), 8.2% showed at least one adverse event¹. Of the adverse events, 83% were judged to be preventable (4). Most of the adverse events were due to medication errors (5).

In low-income countries, health care providers are required to work under increasing workload and with limited resources. In Bangladesh, the admission fee between the public and private hospitals often differs at least tenfold. This is reflected in the facilities of the two categories of hospitals. The large poor population is treated at the public hospitals while a small fraction of citizens can afford private hospital care.

3.2 Working Environment at ICUs

Communication between personnel at the ICU is an important factor for improving patient safety (6). Communicating problems such as stress and asking questions about the handling of machines or other health care related issues will have a positive impact on the ICU. In order to prevent adverse events, it is important that not only the physicians but also the nurses and patient's family are given information about the treatment of the patient (7).

To simplify the work at the ICUs, it is recommended that the patients' beds are clearly labeled and that it is easy to identify the patients. It is also important to have continuous education for the personnel, enough disposable products, different types of support personnel such as assistants or specialists and developing a reporting system for device malfunction and human errors (6).

3.3 Causes of Adverse Events Related to Medical Devices

Often there are mutual root causes to different problems associated with medical devices. Common adverse events are related to medication, unsafe blood, patient care, surgery, anesthesia and obstetric trauma (1). Rather than negligence or poor performance, adverse events are caused by factors such as high workload, inadequate supervision, poor communication, rapid change within organization and deficiencies in system design and operation (1) (8) (9) (10). Health care institutions often respond defensively or secretively, which causes further harm and impairs improvement of the system (1).

¹ "Any injury due to medical management, rather than the underlying disease" (4), (p. 1695)

3.4 Infection risk at ICUs

Since health care-associated infections, or nosocomial infections², are preventable, this kind of infection control is essential (11). Pittet states that the percentage of patients that acquire nosocomial infections can exceed 25% in low-income countries whereas the corresponding percentage in high-income countries is 5-10%. The rise of such infections in the former is ascribed to shortage of resources and basic facilities, malnutrition, comorbidities, immunosuppression and poor personal hygiene. Nosocomial infections in high-income countries often derive from sophisticated and invasive health care techniques as well as multi-resistant pathogens (11).

Maintaining hand hygiene is the most effective method of infection control. The simple measure helps prevent health care-associated infections and the spread of antimicrobial resistance. Still, insufficient maintenance of hand hygiene is a global problem. Other important factors include education for health care workers, an ordered surveillance system of nosocomial infections, relevant legislation as well as consistent implementation of basic infection control measures (11).

3.5 Complexity of ICUs

ICUs are reliant on the well-functioning of equipment and are interdependent on different types of personnel. Use of life supporting medical equipment increases the risk of accidents. Thousands of individuals die annually because of insufficient organization of information and control systems (12). This can be improved using Information and Communication Technology (ICT) (12).

Patient safety is increased if the ICU is run by intensivists, physicians with specific education in intensive care. Multidisciplinary teams will increase patient safety and quality of care and will better prepare the ICU in attending patients suffering from different types of medical conditions. The communication within such teams is important. Good communication between the ICU personnel and the administration is also important and can be accomplished through regular meetings (6).

3.6 Human Resources

The three factors related to the working environment that are closest correlated to adverse events are the quantity of personnel, exhaustion among the personnel and depersonalization (13). In a study in USA, it was found that a nurse-to-patient ratio change from 1:4 to 1:6 increased patient mortality rate by 14 %. The ratio is strongly correlated with emotional exhaustion among nurses (14).

The World Health Report from 2006 (15) states that Bangladesh, together with 57 other countries in the world, has a critical shortage of physicians, nurses and midwives. WHO considers 2.28 doctors, nurses and midwives per 1000 population to be the limit value. In Bangladesh the figure is 0.56 (15). Further, Bangladesh is one of few countries that have fewer nurses than physicians. Today there are approximately three physicians per one nurse (16).

Nurses are securer in their work in the presence of a nurse staff leader (13). The administrative group at the hospital should take into consideration the nurses' perspective when addressing patient safety. Of all categories of health care personnel, the nurses spend most time with the patients. Including nurses in workshops and other meetings is important in order to learn about the shortcomings in their working environment and involve them in the safety work (17). In order to decrease the work load for nurses, lift teams are suggested. A lift team consists of persons that perform tasks without need of medical skills, such as moving patients and cleaning patient areas (6).

² "An infection occurring in a patient during the process of care in a hospital or other healthcare facility which was not present or incubating at the time of admission. This includes infections acquired in the hospital but appearing after discharge, and also occupational infections among staff of the facility" (11) (p. 420)

4 Materials and Method

4.1 Field Study at Six Government and Private Hospitals

The study was conducted through field visits where interviews were conducted during two months (June to July 2012) in Dhaka, Bangladesh. The field study aimed to

- a) identify problems and accidents due to medical device errors at the ICU,
- b) understand the nature and severity of errors and their root causes from a systems perspective,
- c) review the current reporting systems of medical device errors and adverse events and
- d) evaluate the data obtained from 6 different ICUs covering government and private hospitals in Bangladesh.

The field study was conducted at three government hospitals (BSMMU³, DMCH⁴, NICVD⁵) and three private hospitals (BIRDEM⁶, SQUARE, LAB AID). The study collected information to identify

- a) equipment failure,
- b) failure to see results of the test,
- c) errors in the performance of equipment operation,
- d) error in the administrating treatment and
- e) delay in treatment due to equipment disorder, malfunction, system failure, inadequate monitoring or follow-up treatment.

In addition, information on the influence of leadership, risk awareness and workplace condition was collected.

4.2 Data collection

Data was collected through interviews with personnel of professions working at or closely to the ICU. This was done at six hospitals. Due to the time frame, only one person per profession and hospital was interviewed. A dictaphone was used to record the interviews and different questionnaires were used for each category of staff. The questions were constructed based on studied literature on patient safety at hospitals in general and ICUs in particular. Open ended questions were used in order to attain as much information as possible. The questionnaires can be found in Appendix I. Physicians and nurses were asked mainly about the use of medical devices at the ICU and education and training on medical devices. The ICU chiefs were asked about procurement and general information about the ICU. Technicians/engineers were primarily asked about installation, management, use, performance and service and repair of medical devices. The questionnaire was divided into four categories: Contact with the Equipment, Procurement, Maintenance of the Equipment and Staff. The interviews with the chiefs of the ICUs, physicians and technicians/engineers were held in English. The interviews with the nurses were held in Bangla. An observation chart was used to document factors such as noise level and cleanliness. See Appendix II for chart.

The visited hospitals are referred to as G1-G3 and P1-P3 for the three government and private hospitals respectively. In order to keep the respondents anonymous and because the study compares government and private hospitals, not specific hospitals, the matching of the actual names of the hospitals with these references will not be disclosed. The numbering is in no particular order.

³ Bangabandhu Sheikh Mujibur Medical University

⁴ Dhaka Medical College and Hospital

⁵ National Institute of Cardiovascular Diseases

⁶ Bangladesh Institute of Research and Rehabilitation for Diabetes

4.3 Sample

A total of 21 interviews were performed. See Table 1 for information on which categories of staff were interviewed at each of the hospitals. One person from each group was interviewed. There were no biomedical engineers at the government hospitals.

			Hospital			
Position	G1	G2	G3	P1	P2	P3
ICU chief	x	x	x	x	x	x
Physician	x	x	x	x	x	x
Nurse	x	x	x	x	x	x
Technician/Engineer				x	x	x

TABLE 1 – SHOWING SAMPLE SELECTION.

4.4 Data Analysis

The recorded interviews were transcribed. The Bangla interviews were translated before transcription. Information from the transcriptions was compiled in a table. Data analysis resulted in recommendations on methods of increasing the efficiency of medical devices and how to support the collaboration and information exchange, which will be presented through this thesis. These are important for decisions regarding acquisition, inspection, maintenance, reparation and regulations of equipment, as well as the quality of care and patient safety.

5 Results

The cost for admission was tens of times greater at private hospitals than public. Other similarities and differences are presented below. In some areas, results were not obtained from all hospitals and are not mentioned.

5.1 Procurement

Private hospitals experienced that they had all the equipment they needed. The government hospitals clearly pointed out many devices they needed.

None of the private hospitals in the study had a procurement policy. A purchasing committee or managing director procured medical devices at the private hospitals. A government unit procured items according to their procurement policy for public hospitals. The staff at all hospitals agreed that the procurement deciders always opted for the cheapest machines, which could compromise other qualities of the device. At all hospitals, except G3, the ICU personnel were involved in the need assessment for procurement.

At both the government and the private hospitals it took at least six months to obtain a new device. The ICU chief at P2, who had previously worked at a government hospital, said that the government bought many machines because they received a percentage of the price but the machines were kept in store for a long time before being delivered to the hospitals, often they had become useless before reaching the hospital. Both the government hospitals and the private hospitals signed contracts with the supplying companies during the procurement.

5.2 Maintenance

G1 experienced that during the warranty period (which generally lasts three to five years at both government and private hospitals), the company was very sincere in maintaining the equipment as they would have to replace them in case of malfunction. After that the hospital has to pay for maintenance and the company is less inclined to help.

All three of the private hospitals had a Biomedical Engineering Department but none of the public ones did. In case of problems with a machine, the public hospitals contacted the electrical or other type of technical department at the hospital or the providing company. The departments at the hospital did not have expertise in medical technology and could not solve many problems. The provider often took long time to come to the ICU and had to be paid after the warranty period. The private hospitals consulted the Biomedical Engineering Department at the hospital before contacting the company. As a result, equipment maintenance was much better at the private hospitals. Staff at the public hospitals experienced a longer waiting time until the machines were fixed. The physician at one of the public hospitals said that it could take 7-30 days for a company representative to come. The chief at G2 said sometimes the help did not come at all. Then the machines could be off for two to three months. The chief of G3 mentioned that after the warranty period, they sold the machine and bought a new one.

At all of the hospitals except P3, functional tests to prevent device malfunction were only performed when there were apparent faults. At P3, the ventilators were checked after each patient use, i.e. every two to three days. Calibration was performed by the biomedical engineers at the private hospitals. No certain group of people was assigned to calibrate the machines at the government hospitals. In general equipment was not calibrated at any hospitals unless there was an obvious fault. The hospitals mentioned that it was difficult to do calibrations since the machines were used all the time. Machines were used until they were completely out of order at all hospitals except P3, where machines were exchanged when frequent problems were noticed.

At P3, training courses were held for the nurses every week. P2 had fewer and P1 had none. G1 sponsored one to two-week trainings and longer courses could be taken on own expense. G2 held courses but not as frequently as it had done earlier due to organizational changes. At all of the hospitals, the company gave some training to all staff when a new machine was delivered. At P2, weekly lectures were also held for physicians.

The nurses at all hospitals had become adept in maneuvering the machines through experience, not by consulting the manuals. Most nurses were not proficient in English and could therefore not make full use of the manuals. The physicians at all the hospitals answered that they read the manuals sometimes but had become proficient through handling the machines.

5.3 Adverse Events

At two of the public hospitals and one of the private hospitals, staff experienced problems with machines that suddenly stopped functioning. At one of the public hospitals, a patient once died because of it. At another public hospital, nonfunctioning ventilators could go unnoticed for two hours.

Both government and private hospitals seemed to experience infection problems. The chief at P1 said that in order to reduce the infection problems, the personnel sometimes washed their hands, but not regularly.

In contrast to the public hospitals, the private hospitals did not have problems with insufficient inventory (disposable items). If there was a shortage of items at P2, they were bought by the patient's family, the head of the ICU or, in some cases, they were taken from a different patient. The latter was done rarely so as not harm the patient financially. At G1 the same product was sterilized and reused, even if the products were intended for use for a limited amount of time.

5.4 Reporting System

5.4.1 Reporting System for Failure of Machines

P1 wrote a report about malfunctioning machines only if someone from the Biomedical Engineering Department did not come to the ICU immediately. At the same hospital, the nurse-in-charge kept logs on all the machines. At P3, a nurse mentioned that the staff sometimes did not fill in the documentation.

5.4.2 Report System for Human Error

At all of the hospitals, staff reported to their immediate superior in case of errors. At G3 the physician and senior physicians met and discussed the patients regarding causes of death or how to act in specific situations. The senior physicians gave feedback on the doctors' work. All hospitals had a well-functioning handover routine. At five hospitals there was a notebook for writing down patient information. At all the hospitals, except G3, the written handover was also gone through orally with the doctor for the next shift. The nurse at P3 pointed out that it is a problem that this documentation is not always filled in.

At one of the public hospitals, doctors from the different wards of the hospital visited the patients. The nurses from each ward also took part. At all the other hospitals the ICU doctors performed the rounds. The nurses-in-charge (there was one at each ICU) attended the rounds with the doctors and the other nurses were at the bedsides of their respective patients.

5.5 Working Environment

In general, the shifts for nurses were longer at the private hospitals than the government hospitals. See Table 2 for exact lengths.

Hospital	Shift length for nurses [hrs]		
	Morning shift	Afternoon shift	Night shift
G1	6	6	12
G2	6	6	12
G3	6	6	12
P1	12	-	12
P2	8	8	8
P3	7	6	12

TABLE 2 – SHOWING SHIFT LENGTH FOR NURSES AT ICUS

At none of the hospitals were there any formal breaks during working time. The nurses asked other nurses to look after their patient while they had lunch or snacks.

Most of the hospitals strived to have a 1:1 nurse-to-patient ratio. The ratio was hardly met at either the private or government hospitals. In general, there were fewer nurses per patients at government hospitals. All of the hospitals had ward attends to help the personnel with tasks that did not require medical skills, for example cleaning patient areas.

The shift length for physicians varied drastically between hospitals. These are shown in Table 3.

Hospital	Shift length for physicians [hrs]		
	Morning shift	Afternoon shift	Night shift
G1	6	6	12
G2	6.5		12
G3	24*	-	-
P1	12**	-	12
P2	24***	-	-
P3	12	-	12

* The physicians often have to perform operations after this time span and do not finish until 2 pm instead of 8 am, said the doctor.
 ** Sometimes they help other doctors who may be taking an exam, for example. In such cases they can work for 24 hours.
 *** With two additional hours for the morning round.

TABLE 3 – SHOWING SHIFT LENGTH FOR PHYSICIANS AT ICUS

5.6 Risk Awareness

Noise level was lower and the environment calmer at the private ICUs compared to the public ones. The apparent noise mainly included voices, sounds from fans and air conditioners as well as constant sounds from machines. At one of the hospitals, the staff pulled out the cord to the alarm sometimes when the sounds were disturbing and there were no patient problems.

Hand hygiene did not seem to be a top priority at any of the hospitals. Although there were wash basins, the staff did not wash their hands as often as need, for example between handling different patients.

The private ICUs were cleaner than the public facilities. At P2, the machines were cleaned directly after use and put in another room, ready for reuse.

It was found that all of the hospitals were at least moderately in order and easy to work by (clearly marked beds and little disorder around the bed).

At G3, the physician commented that a higher salary would create a sense of responsibility for one's job. He said that sometimes mistakes occur but at present, he did not feel any responsibility and his faults in his work would not be brought to attention or punished.

At none of the hospitals did the staff know how to use the fire extinguishers, although they were mounted on walls in all of the clinics, as legislation demands. At one of the private hospitals there was, however, a fire-fighting department.

Upon arrival of the interviewers and introduction of the project to the two chiefs of ICU at one of the public hospitals, they showed great interest in discovering the findings of this project and suggestions for improvement from the authors. This shows an ambition to improve patient safety.

At none of the hospitals were there clear and complete infection guidelines except P2, where they followed the CDC (Centers for Disease Control and Prevention) guidelines. At this hospital, written protocols were also being developed. They had a hand hygiene program for the care workers.

6 Discussion

The differences between public and private ICUs within the areas of access to, maintenance and calibration of medical equipment, working environment and infection control are discussed below. One of the main reasons for differences is financial. The high admission fee at the private hospitals contributes to a larger monetary resource in comparison with the public hospitals which are funded mainly by the government. Another reason for the differences is the level of accountability to the patients at the two types of hospitals. Since private care consumers pay more for their treatment, such establishments are under larger pressure to deliver satisfactory care. Patients of private hospitals often have the resources to visit several doctors and thereby question the care they receive. The patients at the public hospitals often have lower income and lower status and are thus not likely to be critical of the received care. This works counteractively to the improvement of public hospitals.

6.1 Sources of Error in Study

In an interview situation it is difficult to obtain completely truthful answers. The nurses at the government hospitals shared short-comings of the facilities but the private hospital nurses were more careful to give answers that portrayed the hospital positively. A similar but slighter effect was seen amongst the chiefs and physicians, although the chiefs at all hospitals were more open than other groups.

The interview questions were open ended, to entail in a broad spectrum of answers. A close ended questionnaire had produced results that would have been less open for interpretation by the authors. The sample size was small, which may give an incomplete foundation for depiction and analysis of the situation of patient safety at ICUs in Bangladesh, or even Dhaka.

The interviews with the physicians, chiefs and technicians were held in English. Had they been held in Bangla, possibly more extensive answers would have been obtained.

6.2 Biomedical Engineering Department

A correlation was seen between the maintenance level of the medical devices and the existence of a Biomedical Engineering Department. Although establishing a Biomedical Engineering Department is costly, it is more cost effective than calling an external party (the machine providing company) each time a machine is not functioning or procuring a new device because the current machine is not being fixed. Continuous maintenance will delay and prevent device malfunction.

6.3 Infection Control

With a nationwide shortage of health care providers, leading to a shortage of manpower and a stressful environment at each hospital, it is understandable that hand hygiene is not a top priority. Still, hand hygiene problems need to be addressed. One way to facilitate frequent hand cleaning is to have liquid hand sanitizer at many places within the ICU. In order to ensure patient safety and reduce infection rates, it is important to continuously have education for health care workers, including ward attendants, for example in the form of refreshers' training for nurses.

The causes for nosocomial infections at the government hospitals in Bangladesh coincide with those mentioned in Pittets article (11) for low-income countries: lack of resources and basic facilities, large number of patients suffering from malnutrition, multiple comorbidities, immunosuppression and poor personal hygiene. Considering the high admission fee at the private ICUs, the probability that its patients are malnourished is small.

6.4 Human Resources

Nurses were in general not present in workshops and other assemblies with physicians and chiefs of ICU. Since the nurses work closest to the patients, it is important for their observations of shortcomings in the

system to be brought to attention. It is also important for the nurses to be aware of patient safety procedures and ways to avoid risks. It can be difficult to include the different groups of professionals in large discussion groups, especially in a hierarchical working structure as is common in hospitals in Bangladesh. It could be of interest to form different discussion groups for different categories of professionals and create a discussion platform for representatives from each of the groups. There could for instance be a group for nurses and one for physicians. The nurse-in-charge could be the nurse representative in the latter discussion platform.

Lift teams in the form of ward attendants, who do not have medical skills, are favorable in order to decrease the work load of the nurses, especially when there is a shortage of nurses. However, it can be a potential safety risk if any staff working at the ICU does not have knowledge of hygiene or other patient safety measures. Therefore, it is important that ward attendants are informed about risks and hygiene maintenance.

6.5 Organizational Improvements

Implementation of rules made by authorities should be followed up. An example proving the importance of this is the little knowledge of fire handling strategies among the hospital staff. It was not the intention of this study to observe such strategies but the question arose during the visits and highlighted the difference in the existence of policies and actual implementation.

Documentation of medical device malfunction and human errors should be increased, as it prevents a problem from reoccurring and in the case of reoccurrence provides possible solutions.

Since there is a very high work load in Bangladesh on a fairly limited working force and there is a need for more nurses and technicians at the ICUs, introducing intensivists into the system is not a recommended priority. Rather, using the existing different specialties to create multidisciplinary physician teams would be a more resource efficient way of improving quality of care.

6.6 ICT

ICT tools can be used to improve education and provide further education to health care workers and technicians. Information in the manuals can be made more accessible by presenting it in more interesting forms, for example audio and audiovisual media. These can be published on CD-roms or online using, for example on video sharing web sites such as Youtube and should be produced in the local language for better apprehension. Such material can provide information on the use, management and reparations of common problems related to specific devices. The information should be adapted to the receiver - nurses, physicians or technicians. To prevent the overlooking of patient safety and user safety, these issues can be addressed in the educational material. Although the ICU is a stressful working environment with little or no excess time, such educational forms need to be endorsed. This form of education provides a simple way to convey information, which will lead to more proper use of devices in general but also their more advanced functions and will lead to correct diagnosis and treatment along with avoiding harm for patients and health care workers. Videos can for instance be shown and discussed during the refreshers' training for nurses. Internet forums can be created for technicians to discuss problems regarding the machines. In case of a common problem that has been solved at one hospital, the knowledge can be shared through such a forum. Medical equipment providers could also take part of these forums.

6.7 Medical Devices

Since nurses work closest to the patients, it is important to obtain feedback from them during the needs assessment for procurement. It is important to include users of the devices, the ICU staff, in the procurement at all hospitals.

Regular calibration is important for preventing erroneous results and thereby incorrect patient treatment. An implication of this for biomedical engineers is to design equipment with seldom need for calibration, and make the calibration process simple and quick.

The long waiting time before reparations are performed (mainly at the public hospitals) suggests that biomedical engineers should strive to design simpler equipment with fewer breakable parts, in order to decrease the risk for malfunction. Because single-time use products are being reused, it is desirable to adapt products for multiple time use.

6.8 Further Investigations

This study has identified many of the factors contributing to adverse events in hospitals in Bangladesh. Further studies should focus on gathering more information about each of the factors, especially workplace conditions and handling on machines, since it is useful to acquire more information on these aspects than was gathered through this study. Few results were obtained on reporting systems, but a three month study on reporting systems has been performed at the six visited hospitals from January 2013. Further, it is recommended that further research examine

- a) policies founded by higher authorities (government and other policy makers) that regulate the work at the ICU,
- b) implementation of patient safety measures decided by policy makers or the managements at the ICUs and hospitals,
- c) quality and reliability of clinical testing devices (through interviews with clinical laboratory personnel),
- d) queues for admission to the ICU and
- e) financial loss due to errors at the ICUs in Bangladesh.

Point a) is important as only personnel in direct contact with the ICU were interviewed for this study, but their work is controlled by policies set by higher authorities (government and other policy makers). The lack of knowledge of how to use the fire extinguishers highlights the importance of point b). Point c) was not taken up but is closely related to the work at the ICU. Investigating how many patients are in queue to be admitted to the ICU and the length of the waiting time is important to describe the work load. Therefore, point d) should be studied. Point e) needs to be considered in order to strengthen the importance of improving patient safety. Quantifying the financial toll would make clear the loss that a lack of patient safety implies for hospitals, patients and society and possibly motivate hospitals and higher authorities to invest more in patient safety.

Many of the articles referred to in this thesis have used records from several years of documentation of adverse events. Such protocols should be kept in Bangladesh for comprehensive documentation of events in scientific articles. In order to make recommendations on improvement of patient safety at ICUs for low-income countries, or for Bangladesh in particular, there is a need for more published reports on patient safety in such countries. This study may possibly encourage further work on patient safety in low-income countries.

7 Conclusion

The study has investigated the use of medical devices at ICUs in hospitals in Bangladesh and found that reporting systems, infection control and maintenance of equipment are key improvement areas. Communication between staff could be improved by establishing discussion platforms with representatives from different groups of health care providers. Reporting systems should be developed more. By establishing Biomedical Engineering Departments, maintenance can be improved at public hospitals. ICT tools and other forms of training can be used to increase knowledge about patient safety and equipment use, which can minimize device related hazards. Changes in the design of medical products can also decrease risks. It is important to identify areas of improvement and finding ways to increase patient safety. Doing so will benefit many groups in the society.

Bibliography

1. **WHO.** *Technical discussions on promoting patient safety at health care institutions, Regional committee, Fifty-ninth Session SEA/RC59/Inf.4.* Dhaka : WHO, 2006.
2. **World Health Organization.** WHO South-East Asia Region. [Online] [Cited: May 18, 2013.] www.who.int/goe/publications/atlas/bgd.pdf.
3. **Central Intelligence Agency.** The World Factbook. [Online] [Cited: May 18, 2013.] <https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html>.
4. **Wilson, R M, et al.** Patient safety in developing countries: retrospective estimation of scale and nature of harm to patients in hospital. *BMJ.* 2012, Vol. 344, 7840.
5. **Rothschild, et al.** The Critical Care Safety Study: The incidence and nature of adverse events and serious medical errors in intensive care. 2005, Vol. 33, 8, pp. 1694-1700.
6. **Michigan Health and Safety Coalition.** *A Toolkit for Intensive Care Units to Improve the Safety and Quality of Patient Care.* s.l. : Michigan Health and Safety Coalition, 2004. [Online][Cited: September 14, 2012.] <http://www.mihealthandsafety.org/icu/index.html>.
7. **Pronovost, Peter J.** Developing and Pilot Testing Quality Indicators in the Intensive Care Unit. 2003, Vol. 18, 3, pp. 145-155.
8. **Reason, J.** *contribution of latent human factors to the breakdown of complex systems.* s.l. : Phil. Trans. of the Royal Society of London, 1990.
9. **Charles, Vincent.** Sally Taylor-Adams Framework for analysing risk and safety in clinical medicine. 1998, Vol. 316, 1154.
10. **Rasmussen, J.** The concept of human error: Is it useful for the design of safe systems in health care? 1999.
11. **Pittet, Didier, et al., et al.** 'Clean Care is Safer Care': the Global Patient Safety Challenge. 2006, Vol. 10, pp. 419-424.
12. **Geoghegan, et. al.** *ICT for social welfare.* s.l. : Policy Press, 2004.
13. **Laschinger, Heather K. Spence and Leiter, Michael P.** The Impact of Nursing Work Environments on Patient Safety Outcomes; The Mediating Role of Burnout/Engagement. 2006, Vol. 36, 5, pp. 259-267.
14. **Aiken, Linda H., et al., et al.** Hospital Nurse Staffing and Patient Mortality, Nurse Burnout, and Job Dissatisfaction. 2002, Vol. 288, 16, pp. 1987-1993.
15. **WHO.** Strengthened Health System, Human Resources for Health . [Online] WHO, August 19, 2010. [Cited: September 14, 2012.] <http://www.ban.searo.who.int/en/Section3/Section41/Section69.htm>.
16. —. Strengthened Health System, Nursing Midwifery. [Online] WHO, August 19, 2010. [Cited: November 13, 2012.] <http://www.ban.searo.who.int/en/Section3/Section41/Section98.htm>.

17. **Lin, Laura and Liang, Bryan A.** *Addressing the Nursing Work Environment to Promote Patient Safety*. s.l. : Wiley, 2007.
18. **Kaye, Roy and Jay, Crowley.** *Guidance for Industry and FDA Premarket and Design Control Reviewers Medical Device Use-Safety: Incorporating Human Factors Engineering into Risk Management*. s.l. : Center for Devices and Radiological Health, 2000.
19. **Buchan, James and Calman, Lynn.** *The global shortage of registered nurses*. Geneva : International Council of Nurses, 2006.
20. Truth About Nursing. [Online] April 10, 2012. [Cited: October 10, 2012.] <http://www.truthaboutnursing.org/faq/magnet.html>.
21. Medicine Net. [Online] 14 June, 2012. [Cited: December 1, 2012.] <http://www.medterms.com/script/main/art.asp?articlekey=23392>.
22. **Sandblad, Bengt.** Uppsala University, Inst. för informationsteknologi. *Människa-datorinteraktion i hälso- och sjukvård*. [Online] [Cited: December 1, 2012.] <http://www.it.uu.se/edu/course/homepage/medinf/vt07/OHMDI2007.pdf>.
23. **Lin, Laura and Liang, Bryan A.** *Addressing the Nursing Work Environment to Promote Patient Safety*. 2007, Vol. 42, 1, pp. 20-30.

Appendix I – Questionnaires

The following questionnaires were used as a basis for the interviews with different professional groups.

Questionnaire I – Chief of ICU

About the ICU

1. How many beds are there at the ICU?
2. How many doctors work per shift?
 - a. How many doctors are there in total?
3. How many nurses work per shift?
 - a. How many nurses are there in total?
4. How long has the ICU been active?
5. Is it a general ICU?
6. How many ventilators do you have?
 - a. Other equipment that are needed for the patients?
7. Do you use different brands for the same type of devices?
8. Do you have power support?
 - a. What happens if it fails?
 - b. Do you have mock exercises for management of unexpected events (fire, short circuits)?
 - c. Can you tell us about a case when an unexpected event occurred?
 - i. What did you do?
 - ii. How did you manage it?
 - iii. What problems did you face?
 - iv. How did you overcome them?
 - v. Could you overcome them completely? How did you report?
 - vi. What was the policy level response to such adverse events?
9. Who supervises the work at the ICU?
10. Are nurses present during rounds?
11. Is all staff educated within their working area (ward boys and girls)?
12. Do you have clear and complete infection control guidelines?
13. Do you have medication error surveillance?
14. Do you have regular meetings with the management (or only in need)?
15. How does the procurement work-
 - a. Who decides what the ICU needs?
 - b. Who decides what will be procured?
 - c. Contract deal during purchase – if an error is found on a device, what happens? (Is the company contacted or technician at hospital?)
16. Do you have a procurement policy? (E.g. adjustment to the climate.)
 - a. What is given more weight, sophisticated functions, expense, expected life span?)
17. Who calibrates the devices?

Questionnaire II – Physician

Contact with the Equipment

1. For how long have you been working at the ICU here?
 - a. Were you at a different hospital before that, or also here?
 - b. Do you work here alone or somewhere else also?
2. How many of the functions of an equipment are used, how much is redundant?
3. Do you have comprehensive equipment management? (In percentage- 100%, 80%, ?)
 - a. How do you compensate shortages of equipment? (Eg. Send them to another ward?)
 - b. Can you tell us about a case when you were in need of equipment and did not have it. What did you do?
4. Do you feel you have all the equipment you need?
 - a. What else do you want?

Procurement

5. How do the staff/you learn to use equipment?
 - a. Is it common that the company educate the staff/teach each other?
 - b. Instructions/manuals
 - i. In which language are they?
 - ii. Have you gone through them?
 - iii. How often do you consult them?

Maintenance of the Equipment

6. If there is a fault on the device, what is done?
 - a. How do you report?
7. Do you take precautions to prevent malfunction of devices?
 - a. Are tests performed for this? /Do you do functional test for malfunction?
 - i. How often?
8. Are there any specific factors that you think are problematic and often contribute to problems with the equipment?

Staff

9. How long are your shifts?
 - a. Do you think you enjoy enough holidays?
 - b. Do you suffer from fatigue problems?
 - c. Do you get bored with your job?
10. How do you exchange patient information among staff between shifts?
11. Example: Linköping¹. What would happen if a similar situation would arise here?
 - a. To whom would the incident be reported?
 - b. Would it be done so anonymously?
12. What is the most serious safety problem that you have encountered during your working life? (E.g. Short circuit)

¹ A case in Linköping from 1983 was used as an example of an adverse event. In that case, three patients had died and several injured after a nurse had mistakenly turned off the alarm of a dialysis machine and diluted dialysate was run through the patients. Years later, the court decided it was not the fault of the nurse but of faulty equipment. (22)

- a. Did you take any measure to prevent it from happening again?

Questionnaire III – Nurse

Contact with the Equipment

1. For how long have you been working at the ICU here?
2. Were you at a different hospital before that, or also here?
3. Are the devices cleaned of dirt, bacteria?
 - a. How?
 - b. Who does it?
 - c. How are devices cleaned between usage on different patients?
4. Who makes sure the stock of disposable products, linen, etc. is filled?
5. Do you ever find the inventory of needed products (such as disposable products, medications, linens, intravenous fluids) insufficient?
 - a. What do you do then?
6. Do you have all the equipment you need?

Procurement

7. How do the staff/you learn to use equipment? (Company/teach each other?)
 - a. In which language are the manuals?
 - b. Who reads them?
 - c. How often are they consulted?

Maintenance of the Equipment

8. If there is a fault on the device, what is done?
 - a. How do you report?
9. Does it happen that you get unexpected outcomes?
10. Are there any specific factors that you think are problematic and often contribute to such outcomes?

Staff

11. How long are your shifts?
 - a. How many patients do you work with during one shift?
 - b. During your shift, do you enjoy breaks?
 - c. Do you get interrupted during your work for other things?
 - d. Do you have enough holidays?
 - e. Do you have fatigue problems?
 - f. Are you bored with your job?
12. How do you exchange patient information among staff between shifts?
13. Example: Linköping. What would happen if a similar situation would arise here?
 - a. To whom would the incident be reported?
 - b. Would it be done so anonymously?
14. What is the most serious safety problem you have encountered?
15. What measures were taken to prevent similar problems to develop again?
16. Do you get refreshers' training?
17. Do you have supervisors that supervise your work?

Questionnaire IV - Technician

Contact with the Equipment

1. For how long have you been working at the ICU here?
 - a. Were you at a different hospital before that, or also here?

Procurement

2. Do you have a procurement policy? (e.g. to procure equipment adjusted for the climate.
 - a. What is given more weight: sophisticated functions, expense, expected life span?)

Maintenance of the Equipment

3. If there is a problem you are unable to solve who do you consult?
4. What do you do when you need spare parts, do you have that at the hospital?
5. Do you take precautions to prevent malfunction of devices?
 - a. Are tests performed for this? /Do you do functional test for malfunction?
 - i. How often?
6. How often is calibration of the devices done?
7. When are equipment replaced, at what point?
8. How is the electrical systems maintained?
9. Do you have an electrical load management system to match the use of electricity?
10. What is the most common reason for you to be consulted?

Staff

11. How long are your shifts?
12. For how long during one day are technicians available?

Appendix II – Observation Chart

The following chart was used to record a number of parameters at the ICUs.

Parameter	Alternatives			Comments
Patient areas are uniform (around the beds)	No	Somewhat	Yes	
Disorder around equipment (e.g. cables)	No	Somewhat	Yes	
Marking of beds, medication, etc.	Few	Acceptable	Good	
Amount of people at ICU	Low	Acceptable	High	
Noise level	Low	Acceptable	High	
Temperature	Low	Acceptable	High	
Humidity	Low	Acceptable	High	
Other comments				