A twofold study at the surgical ward in a Kenyan district hospital: the treatment of pressure ulcers and the treatment of femur fractures at young children.

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1 General introduction

It was the first time a student of biomedical engineering of this university went to a hospital in a developing country. Before my departure I had no idea about the research opportunities in the field of biomedical engineering in Kenya. I decided just to go and arrived in a rural area in Kenya where I did my training period at St. Mary’s Hospital. This mission hospital is a district hospital like many others in this part of Africa. In the next chapter, Chapter 2, background information about the hospital and its community will be given.

During the first weeks I got the chance to evaluate all possible research options. The introduction period covered three weeks. The first week I worked with the physiotherapists. Their work consists not only of physiotherapy but also of orthopedic like reducing bone fractures and putting plaster. The second week I visited the maternity ward and the administration. The theatre was visited during the third week. The focus of that introduction lied on the anesthetics. This introduction has lead to two project proposals. The content of the introduction period and the realization of the project proposals are described in Appendix A.

Considering the wishes from the hospital and my own interest, I chose two projects. Both projects are done at the surgical and orthopedic ward at the hospital, called Lucas Ward. The first project has to do with the treatment and prevention of decubitus directed to all patients on the ward. Many patients are bedridden for a long time. The number of patients, staff and equipment that are involved, makes this pressure ulcer study very interesting. Moreover, there is much knowledge about this subject at the Faculty of Biomedical Engineering. The aim of the pressure ulcer study is to investigate the current state of treatment and prevention of decubitus and to extend this to the future. The pressure ulcer study can be found in Chapter 3. After an introduction about the subject some theoretical background and current treatment methods in the hospital are described, followed by a patient study as next part of the chapter. These parts will come together in the discussion wherein also attention is paid to the treatment of pressure ulcers in the future.

The second project is a study on femur fractures with children below the age of seven years. In order to stimulate the healing of the bone traction is applied as such is done at all femur fractures in the hospital. Although the technique has an extra difficulty with young children, namely the influence of fast bone growth, there is no other technique available yet. Applying traction also has many disadvantages for the patients’ health. Lying on a bed for a long period of time will result in the loss of muscle and junction function. Furthermore, a long stay in the hospital can cause a delay in the development of the child. For these reasons the objective is to investigate the possibilities for an adjustment in the treatment process. It is evident that therefore the current treatment method has to be analyzed. The whole treatment process can simply be divided in applying traction followed by the rehabilitation process. Chapter 4 describes this study on femur fractures. The chapter has a similar outline as the previous chapter about the pressure ulcers. However, an additional goal was to search for alternatives for traction. Unfortunately, this was not possible because there was no scientific literature available during my training period at St. Mary’s Hospital.
2 St. Mary’s Hospital

2.1 Introduction
In 1932 the first Ursuline Sisters of Bergen, from the Netherlands, settled as Missionaries in Mumias and began to give medical care to the people. In the early 1940’s the dispensary was extended to a small hospital with semi-permanent buildings. These were replaced by permanent buildings in 1960. In 1971 the first doctor was appointed. In 1983 the last Ursuline Sisters returned to the Netherlands. Nowadays the hospital is owned by the Catholic Diocese of Kakamega. The Catholic mission hospital is situated 1.5 km from Mumias town. Mumias is the center of Mumias Division in the Butere-Mumias District in the Western Province of Kenya. Mumias has a good accessibility from all directions: from Kakamega, Bungoma and Busia by well-maintained tarmac roads, and from other directions by murram roads also well maintained by the sugar company in the village. Mumias Division has an area of 214 km², a population over 122,000 people and a population density of 570 per km². The entire Butere-Mumias District is a rural area and measures over four times Mumias Division.

St Mary’s Hospital is the only large hospital within Butere-Mumias District. The hospital has 264 beds. There are no other large hospitals within a radius of 30 km. Within the radius around the hospital are four government health centers, some small health units run by NGO’s, a number of privately run clinics and nursing homes. Other surrounding hospitals outside the radius are: the District Government Hospital in Bungoma (30 km), Busia (45 km), and the Provincial in Kakamega (35 km). The nearest big city is Kisumu and that lies 75 km away. Today there is also St. Mary’s School of Clinical Medicine. This school belongs to the institution and is situated on its compound. They train Clinical Officers. Almost all students do their training periods at St Mary’s Hospital.

The hospital has a close collaboration with the St. Elizabeth’s Hospital in Mukuma. St. Elizabeth, also owned by the Diocese of Kakamega, is 42 km away. Therefore St Mary’s serves the whole of Butere-Mumias District as well as population from bordering districts.

Figure 1.1: Left picture shows the head entrance of St. Mary’s Hospital, in the other picture nurses are providing childcare somewhere in the area.

The first objective of St Mary’s Hospital is the provision of preventive and curative health care services of good quality at an affordable price for all people in the area (Figure 1.1). The second objective is to contribute to the development of the Mumias division in a sustainable manner by giving employment and providing health educational services within the community.

In November 1999 the Kenyan government declared HIV and AIDS as a national disaster. The pandemic and its effect in the provision of health services made it necessary for the institution to look into the possibility of assisting victims whenever possible within their homes and cultural environment. This is done by a VCT (Voluntary Counseling Center) in the hospital and several types of home based care. VCT centers are widespread over the country.

2.2 Community and health status
Mumias division is one of the most densely populated areas in Kenya and predominantly rural. Its main cash crop is sugar cane since the establishing of Mumias Sugar Company in the early 1970s. The high population has created pressure on land and led to a mismatch between the supply and demand of basic facilities. The average farm size per household is decreasing. This implies that employment opportunities and income from agricultural activities are gradually reducing; a situation which
contributes to the increase of poverty. It also means an enormous pressure on the available facilities i.e. water scheme and supply services, schools, health facilities, while at the same time the people are unable to afford these services.

The incidence of poverty in Mumias Division is slightly slower than the rest of the divisions in the district because of the uplift it gets from the Mumias Sugar Factory. Its per capita income is one of the highest within the Western Kenya region.

The Mumias Sugar Company situated 5 km from the hospital has an important role in the livelihood of the community. Approximately 500,000 people are dependent on the Mumias Sugar Scheme either directly or indirectly. The Sugar Company has also an important contribution to the development of the area i.e. in the fields of education, health care and infrastructure. However, despite an improvement in the cash influx, malnutrition has become one of the top ten causes of death due to lack of variable food supply. This poses a challenge to the stakeholders and policymakers within the community to work out a method so as to ensure constant food security especially in regard to land usage and land tenure system.

Due to male gender in landownership, education, food production and literacy, women are deprived of essential knowledge on good nutrition and food usage. Both are also compromised by reliance on one cash crop, sugar cane. Landlessness as well as poor management of cane proceeds leaves the farmer poor for most part of the year and unable to provide his family.

The stakeholders and policymakers within the community are challenged to address the poverty level within the district as this in turn fosters the growth of diseases especially AIDS in the community.

The late presentation of patients has remained a huge problem, sometimes their disease has become terminal. This mostly affects children who are brought in late by their parents or guardians. Frequently they die within hours of admission or in the outpatient department, despite the commencing of necessary treatment. As much as hospital fees and the economy may be responsible for this sad scenario, the biggest culprit could be ignorance among the community as to what quality of treatment to seek in certain ailments. Therefore a child with anemia or malaria will arrive at the hospital after visiting several private clinics where the parents will have paid for dubious treatment. Blood transfusion in this case is commenced too late. The CBHC (Child Based Home Care) department of the hospital has therefore intensified health education programs in the community in order to educate the public. In general the competition with private clinics and nursing homes as well as traditional healers is intense. It is difficult for the community to know when the traditional healer may be adequate and when to seek hospital treatment where all facilities and qualified staff are available.

2.3 Patient services

The total number of beds amounts to 264 beds in the hospital. In Lucas ward, the surgical and orthopedic ward, there are 36 beds. The last year the bed occupancy rate and the total number of admissions in the hospital are decreasing due to increasing poverty. The number of patients fluctuates over the year: the highest number of admissions is during the raining season, which stretches approximately from April to June. During the time of this study, from September till December, the number of patients was obviously decreasing. Around Christmas the lowest number of patients is admitted to the hospital.

The hospital receives all kind of patients. Due to poverty, many patients are not able to pay their hospital bills. For many years malnutrition, malaria and anemia are a big problem, especially among young children. The HIV/AIDS epidemic continues to pose a major health problem with the number of diagnosed cases increasing. Table 2.1 gives an overview of the most important diagnosis in the hospital. The disease pattern remains the same the last years. Malaria is the main reason of admission in all age groups, and most cases of anemia were caused by malaria. However, most malaria cases are during the raining season. In Lucas Ward bone fractures, gastro-enteritis and wounds are treated.

A lot of patients die in the hospital. The death rate in the hospital is about 8%12. Some of these deaths could have been prevented if they had been brought in earlier. Malaria remains the most important cause of death; this figure increases when the deaths due to anemia as a result of malaria are included. The death caused by AIDS will also be higher if the deaths from AIDS related illnesses such as tuberculosis, pneumonia, malnutrition, gastro-enteritis are considered.

Finally, each ward has a medical and clinical officer. At Lucas ward the surgeon is the acting medical officer. Ward rounds are daily done by a clinician. Reviews in the wards are done every evening and during the weekends by the medical officer on duty.
Table 2.1: An overview of the most important diagnosis in the year 2001 (Source: year report 2002).

<table>
<thead>
<tr>
<th>ADULTS</th>
<th>CHILDREN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>Malaria</td>
</tr>
<tr>
<td>Incomplete abortions</td>
<td>Pneumonia</td>
</tr>
<tr>
<td>Fractures</td>
<td>Gastro-enteritis</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Anaemia</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>Malnutrition</td>
</tr>
<tr>
<td>Septicaemia</td>
<td>Septicaemia</td>
</tr>
<tr>
<td>Anaemia</td>
<td>Burns</td>
</tr>
<tr>
<td>Dysentery</td>
<td>Neonatal sepsis</td>
</tr>
<tr>
<td>Wounds</td>
<td>Meningitis</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>Measles</td>
</tr>
</tbody>
</table>

2.4 Staff and Management

The hospital management consists of the administrator, the medical officer in charge and the matron (“nurse in charge”). Each directs its own crew. The matron manages all 105 nurses. The medical officer in charge directs the 33 employees of the medical staff e.g. other medical officers, a clinical officer, physiotherapists, anesthetists, pharmacists and lab assistants etc. The administrator is responsible for some 52 employees like the administration officers, technicians, cleaners, and the kitchen and laundry staff. This adds to a total of 190 people working in the hospital in November 2003.

2.5 Finance

One of the major problems for the hospital remains raising funds. The running costs in the hospital and PHC (Patient-Homebased-Care) program solely depends on patient fees. For obvious reasons these fees are kept as low as possible. The other costs have to be paid from donations. Two important donators are the Mumias Sugar Company and the Dutch non-governmental organization Memisa, nowadays part of the international organization Cordaid. There are no government or donor grants for recurrent expenditure. Furthermore, the Afrika Fonds from a Dutch hospital is a continuous support in effort and to improve services.
3 Pressure ulcer study

3.1 Introduction

3.1.1 Definition and classification of pressure ulcers
Pressure ulcers are defined as localized areas of degenerated skin and underlying soft tissues, caused by sustained mechanical loads. The sustained mechanical loads could be pressure, shear and friction. Besides these forces the patients’ general condition is an important factor. In the hospital pressure ulcers are referred as bedsores. Since this covers only some aspects, the term is less correct then pressure ulcers or decubitus ulcers or simply decubitus. Sustainable mechanical loads such as when sitting in a wheelchair or wearing a lower-limb prosthese could also lead to pressure ulcers.

In general the most common pressure points are: sacrum, ileac crest and in-between buttocks, shoulders, inner or lateral aspect of the knees, prominences of the head, ankle area, the heel and elbow. The pressure sore can develop either superficially or from within the deep tissue. Animal studies demonstrated that this difference depends on the nature of the surface loading. Shear stresses within the skin layers is the main cause that leads to the superficial type, formed in the skin. This superficial type is characterized by maceration and detachment of superficial skin layers and may transform to an ulcer when progressing. Deep ulcers arise in muscle layers covering bone prominences and are mainly caused by sustained compression of tissue. In fact deep ulcers are more harmful because they develop at a faster rate than superficial ulcers and yielding more extensive ulceration. In addition, the initial pathologic changes are in the deep tissues and therefore are difficult to identify. Necrosis of muscle, fascia, and subcutaneous tissue may occur even at a stage when the skin shows only minor signs of tissue breakdown. Thus clinical intervention may be too late when the deep pressure ulcer becomes visible. Either superficially or deeply arised pressure ulcers can be classified as in Table 3.1. In general, when assessing dark skinned individuals, careful visual inspection is very important. This should be done with good lighting and tactile inspection of vulnerable areas. Tactile inspection is done to detect changes in temperature, either warmer or cooler, and to detect induration. The classification presented here is just a practical way to define the seriousness of pressure ulcers. Although the degree of damage may not always be obvious to the eye, this type of identifying can help to set up a plan of treatment either to heal the wound or to prevent the wound to become worse.

Table 3.1: Pressure ulcer classification scheme (Source: EPUAP, 2003)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>Non-blanchable erythema of intact skin. Discolourisation of the skin, warmth, edema, induration or hardness may also be used as indicators</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Partial thickness skin loss involving epidermis, dermis or both. The ulcer is superficial and presents clinically as an abrasion or blister.</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Full thickness skin loss involving damage to or necrosis of subcutaneous tissue may extend down to, but not through underlying fascia</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Extensive destruction, tissue necrosis, or damage to muscle, bone, or supporting structures with or without full thickness skin loss</td>
</tr>
</tbody>
</table>

3.1.2 Aim and outline
Patients at Lucas ward have a high risk of developing pressure sores. The occurrence of pressure ulcers is rare at the other wards; isolation is the only ward that also has patients with bedsores regularly. At Lucas ward many patients are bedridden for several weeks, because they have a reduced mobility due to strokes, fractures, hernia’s, etc. A patient of Lucas ward sees the outpatient department as all patients do. Some patients see theatre as well and could have developed the disorder there. Therefore some parts of the study are extended to those departments.

The main focus of the entire pressure ulcer study lies on treatment and prevention of pressure ulcers at Lucas ward. Both are sometimes referred to as treatment as well. Prevention is defined as to prevent the development of bedsores or to prevent bedsores to become worse. The treatment of pressure ulcers involves three main strategies:

1. Local treatment of the wound using dressings and other topical applications;
2. Pressure relief, using beds, mattresses or cushions, or by repositioning the patient;
3. Treating concurrent conditions that may delay healing (e.g. poor nutrition, infection).
The study has an epidemiological and empiric character and includes an analysis of the treatment and prevention of the disorder with a theoretical background but also a patient study at the ward to determine the prevalence of bed sores, the size of the risk population and finally, the measure of occurrence of the disease and of the seriousness. Devices in relation to the treatment and prevention of pressure ulcers are evaluated and perhaps new devices can be developed for this goal. Maintaining the low costs for the hospital and the patients is an important goal within this study.

3.2 Theoretical background

3.2.2 Wound management

In scientific literature there is no agreement about the treatment of pressure sores. This paragraph is mainly based on the EPUAP-guidelines and Dutch guidelines. It is supposed that the nursery can identify the grade of a pressure sore, although no graduation can be found in their textbook that lies on each ward. If only looking at the wound without defining any grade, some general remarks about pressure ulcers could be made. First of all, necrotic tissue has to be removed in any case. Secondly, the treatment must prevent local infections. Furthermore, covering the wound should keep the wound milieu warm and moistly but the strapping should not be too tight. At last, improving the general condition of the patient contributes to the prevention and healing of bedsores. Moreover, moisture lotions are advisable to prevent dryness and cracking of the skin. When considering the grade of the decubitus more specified advice could be given about the treatment (Table 3.2). This table shows that treatment advice remains common and that the clinical opinion of an expert is important in any case. Therefore specific actions in local wound treatment are discussed as well; these are referred to as cleansing, debridement and dressing.

<table>
<thead>
<tr>
<th>Grade 1</th>
<th>It is not necessary to take extra measures besides the preventive measures. However, more emphatic attention to pressure relief and repositioning is recommended.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 2</td>
<td>To use dressings or not in order to stimulate healing depends on the size, location and the amount of exudation of the wound. Furthermore, sink oxygen crème can be applied locally.</td>
</tr>
<tr>
<td>Grade 3</td>
<td>If necessary, necrotic tissue has to be removed by repeated necrotomy. The wound should always be covered with a dressing. The necessary amount of changes depends on the location, size and amount of exudation of the wound. Dry necrotic tissue on the heels should be reserved of the underlayer.</td>
</tr>
<tr>
<td>Grade 4</td>
<td>First of all necrotic tissue has to be removed mechanically. It is desirable to use a sterile blade and pincet. If mechanical removal is impossible, there are some other options.</td>
</tr>
</tbody>
</table>

Cleansing

According to scientific literature it is preferred to use normal saline without a preservative since it is reported to be non cytotoxic and cleansing agents with preservatives or inert carriers may be cytotoxic. Antiseptics like povidone may be toxic to regenerating cells and should be avoided. Irrigation of the wound with the cleansing agent may be done with squeeze bottles, syringes or the like. In order to remove exudates and sloughing tissue from the wound some gentle mechanical force or pressure should be used rather than simply spraying the wound and patting dry. If necessary, analgetics can be delivered to release the pain because changing dressing and doing a wound toilet can be very painful.

Debridement

When it is observed that cleansing alone is not sufficient to remove devitalized tissue from the wound bed, debridement is appropriate. Debridement is the removal of necrotic tissue and wound debris. There are several methods to do debridement, e.g. autolytic, mechanical, chemical, sharp and surgical debridement. Autolytic debridement is achieved using an occlusive or semi-occlusive dressing that retains moisture and liquefies necrotic tissue by phagocytosis, and tissue enzymes. Mechanical debridement is achieved non-selectively using physical force such as wet-to-dry dressings, lavage, whirlpool and other methods to loosen foreign materials and contaminated tissues and healthy tissue as well. Chemical debridement employs the use of tropical proteolytic or collagenolytic enzymes to loosen and liquefy eschar, slough and wound debris. Sharp debridement selectively removes necrotic tissue, using sterile instruments, but without anesthesia and with little or no bleeding. This is closely related to surgical debridement, in which much more aggressive excision may be done.
**Dressings**
Wounds heal better in a moist environment. Dressings help creating a moist wound bed and dry surrounding tissue and control exudates without desiccating the ulcer bed.

### 3.2.3 Electrical stimulation (ES)
A number of adjuvant therapies to promote wound healing have good evidence to support implementation and others are emerging today. Only electrical stimulation is discussed here because this has showed good results and could be implemented in the hospital. The literature review is extensively done in order to inform the hospital staff about the new technique completely. Much information is collected from the article of Janssen et al.

Not much research is done yet to investigate the effects of ES treatment on wound healing. The randomized clinical trials are mostly small scale and have different treatment outcome measures, but there is evidence that ES is useful in clinical practice for pressure sore prevention and for wound treatment. In this section some of these clinical research into the effectiveness of pressure sore healing are quoted.

Likewise several studies are done to find out how ES and ES-induced exercise could reduce the pressure sore risk. Unfortunately, the lack of controlled studies is a serious problem. This is mainly due to the difficulty of including sufficient subjects in these cumbersome studies. From these studies there is no hard evidence yet whether ES-induced exercise can prevent the incidence of pressure sores. Nevertheless, these studies are also discussed in this section because it is clearly proven that ES and ES-induced exercise can have positive effects on factors reducing the risk of pressure sore development. In relation to decubitus the main focus is to reverse muscle atrophy and to stimulate poor blood circulation.

After these ES studies on the treatment of wound healing and the reduction of pressure sore risk are discussed, information is given about how to apply this technique in the hospital.

#### ES treatment on wound healing
Gentzkow et al studied 40 non-healing stage III and IV pressure ulcers in 37 patients, ranging in age from 29 to 91 years. They utilized LVDC for 30 minutes twice daily, during four weeks. The primary study outcome was the relative change of the ulcer area as defined by the width of the ulcer, multiplied by its length. At the end of the treatment period, the treatment group showed an average of 49.8% wound-healing area, versus 23.4% in the control group. They also found that individuals who had a metabolic condition (such as diabetes) and females showed improved healing, whereas individuals who had tunnels undermining the wound or a more advanced-stage wound showed less healing.

Wood et al. did a larger randomized clinical trial on the efficacy of pulsed LVDC. ES was applied 3 times per week during a few hours in a period of 8 weeks, or until the wound fully healed. This was done with 71 subjects (±75 years) with stage III and IV ulcers who had shown no significant improvement in 5 weeks. These subjects were randomly assigned to the treatment group or to a control group that received conservative wound treatment. Results showed that treatment increased the healing rate significantly: 58% of the ulcers in the treatment group healed in 8 weeks, compared with a 3% healing rate in the control group.

Gardner and co-workers have done an extensive meta-analysis on effects of chronic wound healing. They looked at fifteen studies, including 24 ES samples and 15 control samples. The average rate of healing per week and 95%-confidence intervals were calculated for the ES and control samples. Rate of healing per week was 22% for ES samples, and 9% for control samples. The 95%-intervals of ES (18-26%) and control samples (3.8-14%) did not overlap, indicating a significant improvement of ES treatment over control treatment. ES was most effective on pressure ulcers, more than on venous ulcers or other type of wounds. The samples were subsequently grouped by type of ES device and chronic wound and reanalyzed. However, findings regarding the relative effectiveness of different types of ES device were inconclusive.

#### ES-Induced Exercise and pressure sore risk
**Muscle size**
People with spinal cord injury often have severe atrophy of the muscles below the lesion level. Voluntary muscle contractions that would prevent muscle atrophy are not possible below the lesion, but contractions in the paralysed muscles can often be induced using ES, potentially countering muscle atrophy. For endurance exercise, a leg cycle ergometer (LCE) has been developed which is pedaled via ES-induced contractions of the paralysed lower-limb muscle groups. Although several studies have shown that atrophy of the paralysed muscles can be (partially) reversed in different areas by ES-induced resistance exercise techniques, limited data is available of the gluteal region in those with
spinal cord injury. Since this area is more relevant for pressure sore prevention then the thigh area where most research has focused on, only these outcomes are discussed here.

Hjeltnes et al. revealed that only 2 months of ES-LCE training in individuals with long-standing spinal cord injury resulted in significant increases in cross-sectional area's of the quadriceps (+38%), hamstrings (+17%), and the gluteus maximus (+27%). The study performed by Baldi et al. showed that ES-LCE exercise training during the first 6 months post-injury could prevent the occurrence of gluteal muscle atrophy seen in a non-exercising control group. This control group lost an average of 27% of gluteal lean mass during this period, whereas the ES-LCE group showed an increase of 5-10%. A third group that underwent unloaded ES-induced contractions of the gluteal muscles showed less atrophy than the control group, atrophy still occurred (5-10%) suggesting that dynamic loaded contractions may be necessary to fully prevent muscle atrophy after a spinal cord injury.

Peripheral circulation

A poor peripheral circulation could contribute to the development of pressure sores. People, who are confined to a bed or wheelchair, generally have a reduced circulation. Muscle activity is chronically reduced resulting in structural changes to the vascular bed supplying the muscles. Blood flow to tissue is governed by perfusion pressure and vascular resistance; since the former is normally maintained within narrow limits, the latter controls a large part of the variation in blood flow. The leg vascular resistance is dramatically enhanced in people with spinal cord injury. Therefore, these people have a poor peripheral circulation. A way to counteract these problems is to increase again muscle activity, which would augment blood flow, and if performed for a longer period, reverse the vascular atrophy. Since voluntary exercise is not always possible, such as in individuals with paralysis, in patients who are unconscious, and many other bedridden patients, ES could be used to induce the needed exercise. Several studies have indeed shown that this way of induced exercise can increase blood flow to the stimulated muscles. Again most research has focused on the thigh region, e.g. the blood flow in the femoral artery. However among others Levine et al. measured blood flow under the ischial tuberosities of seated able-bodied individuals and bodies with spinal cord injury during ES of the gluteal muscles. All subjects showed an augmented blood flow during ES-induced contractions. Thus ES can stimulate acute adaptations and hence, helps to prevent pressure sores. Other studies showed that ES-induced exercise could also be used to stimulate chronic adaptations. It is proved that the resting blood flow markedly increases in the femoral artery of individuals with spinal cord injury as well as in the skin. But it is important to realize that only activated muscles show an increased blood flow, indicating that it is essential to stimulate those areas that are at risk of pressure sores. Furthermore, recent studies by Gerrits et al and Chilibeck et al showed that ES-LCE training also increases the vessel diameter in the thigh region.

Technique

Potential wound healing mechanisms

Potential wound healing mechanisms are considered at two levels, i.e. cell level and organic level. When considering at cell level: neutrophil, macrophage, fibroblast, and epidermal cells are involved in wound repair. All these cells carry either a positive or a negative charge. When these cells are needed, ES facilitates galvano-taxic attraction of these cells into wound tissue and thereby accelerates healing. ES also has a stimulatory effect on cells, resulting in more receptor sites for growth factors, stimulation of growth of fibroblasts and granulation tissue, and preventing post-ischemic oxygen radical-mediated damage. Furthermore, the number of mast cells decreases in healing wounds if exposed to ES. Mast cells are associated with diseases of abnormal fibrotic healing. Research at organic level showed that ES increases blood flow and reduces edema. As the major colloidal protein in blood, albumin, is negatively charged and is repelled by negative polarity, electrical stimulation cause fluid shifts. Furthermore it is clinical observed that negative polarity facilitates debridement of necrotic wound tissue, stimulates neurite growth, and induces epidermal cell migration. ES also inhibits bacteria from growing and from migrating into the wound10. All these effects are contributing to acceleration of wound healing. Therefore, ES seems to have a clinical additional positive effect.

ES and ES Characteristics for tissue repair

The basic technique to induce muscle contractions for exercise via ES involves the use of an electrical stimulator providing impulses to skin surface electrodes placed over the muscle to stimulate action potentials that would normally come from the central nervous system. These impulses evoke action potentials in the motor neurons entering the muscle. The action potentials subsequently activate the neuromuscular junctions to release acetylcholine, evoking action potentials in all of the muscle fibers of the motor units, and thereby inducing muscle contractions. Thus, it is desirable to place electrodes directly over motor points to obtain optimal muscle performance at relatively low ES current. Impulses
are typically delivered at a frequency of 30-50 Hz to induce smooth, titanic contractions. Contraction strength can be varied by adjusting the ES current intensity since this directly relates to the number of motor units activated. During exercise muscles become exhausted. The muscle fibers undergo progressive fatigue and their force output decreases. The rate of fatigue for ES-induced contractions is most likely higher than for voluntary contractions due to the non-physiological activation technique, histochemical changes in the paralysed muscle fibers, and reduced circulation of blood. To compensate for fatigue, ES current intensity must be progressively increased during the exercise to recruit fresh, non-fatigued muscle fibers which is automatically accomplished in advanced electrical stimulator systems via performance feedback circuitry. However, once the maximal current output intensity of the stimulator is reached, muscle performance will decrease and become insufficient to maintain exercise.

Three basic stimulation modalities are distinguishable: low-voltage direct current (LVDC), high-voltage direct current, and low-voltage alternating current. There is a great variety in the electrical parameters among the three basic modalities as well as within each modality. Applied currents may be direct, alternating, continuous, or pulsed and waveforms may be continuous, peaked, sinusoidal, square, or triangular.

Several studies suggest that placement of the anode in a direct current circuit directly over the wound enhances tissue healing. Evidence for the use of the anode over the wound with direct-current amplitudes below 1 microampere for enhancement of wound healing is strong. In some applications of monophasic pulsed current the cathode is placed initially in the wound area followed by a reversal to positive polarity (anode) after several days of treatment. In some applications the reversal is done periodically throughout the healing period. The total energy delivered to the affected tissue and electromagnetic changes in the wound environment depends on the current density. Current density is determined by the electric current intensity and the electrode size, shape and placement. When electrodes are placed further apart a deeper electric current will penetrate body tissues.

3.2.4 Pressure relief
Repositioning of the patient
The worldwide advice is to reposition the patient every 2-4 hours during day and night to prevent bedsores. Individuals, where appropriate, should be encouraged to reposition themselves if this is possible. Local mechanical stresses and strains within a tissue need to be reduced. However, this is not necessary achieved by reducing an external pressure applied to the skin surface. Nevertheless positioning on pressure sores and the bone prominences should be avoided, unless this is impossible because of the general treatment goals. Correct positioning or devices such as pillows should be used to keep bone prominences from direct contact with one another. Lifting devices that facilitate moving patients up in bed or turning from side to side may reduce exposure to friction. Heels should be elevated on a pillow sufficiently to raise the heels off the support surface providing complete pressure relief. This means that latex gloves filled with water should not be used. A good position could be the well-known Fowler position that could help to prevent pressure sores or to prevent to become worse (Figure 3.1). Wind rings should not be used to create areas of reduced pressure.

Figure 3.1: The upper figure shows the 30° semi-Fowler position from side view. The figure below shows the Fowler position from top view; cushions are added.
The technique of repositioning is just as important as the repositioning itself. Therefore devices to assist manual handling may be used during transfer and positioning of patients to minimize shear forces. At last, previous studies showed that many times decubitus was developed within two hours under anesthesia in the theatre. Therefore repositioning on the operating table is as much as important on the ward. This is likewise for the outpatient department.

**Beds, mattresses and sheets**

For beds it is preferable that head side and feet side are adjustable and that the construction and material prevent the mattress from moving. Several types of mattresses have been especially developed for patients with pressure sores, but these mattresses are not widely available in the region and too expensive for a district hospital. For these reasons they are not discussed here, although a good mattress is important when preventing for bedsores. In order to prevent friction on the skin it should be wishful to keep the bottom sheet dry and tightly straight to prevent wrinkles.

### 3.2.5 Concurrent conditions

Just two concurrent conditions are highlighted, namely the nutrition state and the education level in relation to pressure ulcers of the health care providers and the patient and his relatives. Other concurrent conditions may be diseases like anaemia or diabetes, which cause a higher risk to develop decubitus. It is evident that these diseases have to be treated.

**Nutrition**

A poor feeding condition or a declined food intake results in a deficit of proteins and energy. Wound healing is delayed because of this deficit. In order to avoid malnutrition or to raise the current malnutrition, it is important to give the patient a balanced diet. A high protein diet is highly recommended for all patients who are at risk or have decubitus.

**Education level**

Education can help to improve the outcome for patients at risk of pressure damage. Educational programs should be available for health care providers, patients and relatives. The program should include the following items: pathophysiology and risk factors for pressure damage, risk assessment tools and their application, skin assessment, selection and instruction in the use of pressure redistributing and other devices, development, principles of positioning to decrease risk of pressure damage, health promotion and clarification of responsibilities for all concerned with this problem. This means that the patient and his relatives should be familiar with and understands the necessary actions for treatment of the sores in order to participate actively. It is important to give good information and instruction during the whole treatment. This means that the ones, who provide the information, have to be very familiar with the treatment of decubitus.

For good treatment of pressure ulcers the ward staff needs many information about the condition of the patient. Something like a risk scale could be introduced to assess the patients’ risk to develop decubitus but only if it is functional. There is the danger that the nurse or someone else just fill in the form and does not undertake the necessary action. It is even known from European countries that they fill in the form after all. In such cases a clinical opinion from an expert results in better care and prevention than the use of a risk scale.

### 3.3 Current methods

#### 3.3.1 Wound management

**Cleansing**

Normally, normal saline (sodium chloride) is used for cleansing wounds in this hospital. When the wound is dirty or infected, normal saline and hydrogen peroxide are used. In some cases cane sugar, which is normally used in households, is sprinkled to stimulate wound healing in the yellow parts of the wound. Povidone is rarely used to cleanse the wounds. Generally the nursery practice some gentle mechanical force or pressure to cleanse the wounds. In order to protect the skin from bedsores sink oxygen crème is used. This is done around bedsores that already occurred and near bone prominences at high risk.

**Debridement**

In the hospital debridement is done with a blade by nurses or clinical officers. The worst cases go to theatre and undergo anesthesia in order to remove the necrotic tissue by the surgeon. From all the advanced methods as mentioned in 3.2.1 only these sharp and surgical debridement are applied in the hospital. It is demonstrated that sharp and surgical debridement are the most appropriate when the bacterial...
load of the wound may evolve into spreading cellulites and sepsis.

**Dressings**

Many types of dressings are available worldwide but these are occasionally introduced in the hospital through donations. Because the advanced dressings are not common there is still a lack of knowledge how to apply donated dressings. In fact the ordinary way of dressing is preferred in the hospital. Requisites for dressings are just sterile gauzes and strapping. Both are cheap and widely available in the hospital. The nursery in theatre is responsible for cutting the gauzes from a roll, folding them into rectangles and then to sterilize the gauzes in the autoclave. All gauzes are about the same size. The nursery prefers this type of strapping above the leucoplast. Superficial wounds are covered with the gauzes and strapped at the boundaries(Figure 3.2). Deep wounds are packed loosely and also strapped at the boundaries.

3.3.2 Local Electrical Stimulation

St. Mary’s Hospital possesses an electrical stimulator but that one is not in use because it has broken down. The electrical stimulator is for repair at Elizabeth Hospital (Mukumu) and has been therefor a long time. The stimulator is suitable for using it on wounds. However, the physiotherapists have to be instructed how to use the equipment for that goal.

3.3.3 Pressure relief

**Repositioning**

The nurses make sure that patients turn or are turned regularly. In difficult cases the physiotherapist is appointed as the responsible staff member for the repositioning technique. Latex gloves filled with water are used to prevent heels developing pressure ulcers. Just 3 wind rings are still in use since the hospital acquired 10 of them; the others are lost. It is observed that the wind rings often have direct skin contact and are moved from one patient to another without sterilizing or cleansing. Thus currently, the wind rings could transfer infections.

**Beds, Mattresses and Sheets**

In general the beds are not adjustable; they are made of steel. The bed base has a steel mesh. The mattresses can easily shift on the bed. The inner side of the mattresses is made of foam and is covered with smooth imitation leather. Because of the age of the mattresses many covers have cracks and many mattresses are deformed due to the patients’ weight. The original thickness of the mattresses is estimated about 8 cm by measuring the thickness of several mattresses at the far ends. There are two types of sheets available on the ward: the first one is meant for daily use in the wards, the other one for transport in the hospital. The latter is also used daily and does not match with the size of the mattresses: they are significantly shorter in length. The former matches better but still not very well. Both sheets can easily move on the mattresses and are missing elastic bands at the margins.

3.3.4 Concurrent conditions

**Nutrition**

A patient who is able to eat normally can get four types of diets in the hospital: normal diet, light diet, high protein diet and diabetic diet. The normal diet is in accordance with the traditional nutrition; porridge is served as breakfast, as lunch the patient gets a mixture of maize and beans and a combination of ugali, stew and greens is served for supper. Between the meals the patients get tea with white bread. The normal diet is highly rich of carbohydrates and has a lack of nutrients like vitamins and minerals. The light diet is mostly given to post-operative patients and contains fewer carbohydrates. The diabetic diet is something like the normal or light diet but with less sugar. For the high protein diet there are additions to the normal diet like chicken or fish and more vegetables and is more delicious as well. A high protein diet is highly recommended for all patients who are at risk or have decubitus.

Normal diet is cheaper than the other diets. For other diets than standards the patient have to pay an extra 150 KSH above the normal 400 KSH for the daily care costs in the year 2003. Because the high protein diet is more expensive for the patients, many patients do not take that diet. Sometimes the relatives give the patient some additions in order to make the normal diet more nutritious.

**Education level**

No risk assessment tools are known in the hospital. Generally the physiotherapist and surgeon are responsible for undertaking action to prevent pressure ulcers. The surgeon is the only staff member at the ward who has the knowledge to distinguish the different stages of ulcers. The physiotherapist is more responsible for the treatment of ulcers over time. The nursery treats the ulcers according to the advice of or with the assistance of the physiotherapist.
3.4 Patient study

3.4.1 Aim and outline
The main objective is to investigate the state of decubitus at the surgical ward. This includes a patient study to determine the prevalence of pressure ulcers, the size of the risk population and at last the measure of occurrence of the disorder and of the seriousness. To achieve this objective a risk assessment is done for all patients at the surgical ward. The prevalence is measured as well in order to know how many patients really develop decubitus. Pressure ulcers and the condition of the corresponding patients are observed as long as they are in the ward. Factors associated with pressure ulcer risk are many and includes medical diagnosis, co-morbidities and previous medical events, patient demographic characteristics, anthropometrical characteristics, physiological status, nutritional status, functional status, cognition, psychological status, social behaviors, knowledge and adherence, and nursing care of facility characteristics \(^1\). It should be obvious that not all these factors can be analyzed in this short research period. Although models from America and Europe are in use to collect data from the patient, only those factors are analyzed that seem to be relevant to a patient and his treatment in this kind of hospital in this area. This also means that there could be some restrictions to implement the models.

3.4.2 Methods

**Risk assessment**
Filling in a score list resulted in a risk assessment (Table 3.3). This list is a combination of the Braden score list, worldwide in use, and the Dutch CBO-scale \(^7\). The Braden score list can be found in Appendix B. The assessment was weekly done together with one of the physiotherapists in the hospital. Sometimes doctors notes were used or questions were asked to the nursery or the patient to find out the answer. Unfortunately, the first time this method was not possible due to the huge amount of work and the regularly absence of the physiotherapists in that period. Reading the doctor’s notes, asking questions to the nursery and an own observation at the patient’s bed has resulted in that first assessment.

<table>
<thead>
<tr>
<th>Physical condition</th>
<th>Neurological diseases</th>
<th>Incontinence</th>
<th>Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consciousness</td>
<td>Skin condition</td>
<td>Feeding condition</td>
<td>Temperature</td>
</tr>
<tr>
<td>Mental condition</td>
<td>Shear stresses</td>
<td>Way of feeding</td>
<td>Anaemia</td>
</tr>
<tr>
<td>Mobility</td>
<td>Medication</td>
<td>Age</td>
<td>Hypotension</td>
</tr>
<tr>
<td>Sexe</td>
<td>Other notes</td>
<td>Cause of admission</td>
<td></td>
</tr>
</tbody>
</table>

It is necessary to clarify how shear stresses as well as mobility is determined. A patient has no shear stresses when he is able to turn by himself and has a normal sensory perception. An indicator to define the measure of shear stresses is the position of the patient in bed as well as the way of support by cushions or blankets. Furthermore different types in mobility are distinguished: the patient is bedridden and completely immobile in bed, the patient is bedridden but able to turn in bed, the patient is not completely bedridden, and the patient is not bedridden.

**Determining the prevalence**
Clinically there are three methods in use to obtain prevalence figures: 1) written questionnaire, 2) retrospective dossier inquiry and 3) testing patients with increased risk. The method in use is as follows: once a week all patients, adults and children, are counted at the ward. Patients that are already discharged are taken into account as well. The men-women ratio is calculated. Also the number of patients who developed decubitus is counted. Only the patients that developed decubitus in the hospital are taken into account. But patients that have developed the disease at home are noticed as well. The first measurements were done at Fridays. At Friday there are less patients then at the beginning of the week. Therefore the measurement moment has been changed to Monday. Only stadium II till IV bed sores are taken in the list, because the first stadium is hardly to recognize at dark people and not acknowledged as decubitus in the hospital and hence, that stadium is not treated as a bed sore in the hospital.

**Observing patients who developed decubitus**
Each patient who developed decubitus is observed. Twice a week the wounds are considered: dimension, location, presence of necrotic tissue, amount of exudates and presence of granulation tissue. The dimensions, e.g. shape, length, width and depth, are used to estimate the size of the area. Also the
grade is attached to each wound. Furthermore the given treatment concerning cleansing, debridement and dressings is considered. In the first period anthropologic parameters like body weight and length were included. However, the body weight is unknown due to the fact that this is not measured when a patient is admitted. It is also not possible to weight a patient when he is in traction or has plaster. Thus it was not possible to calculate the Body Mass Index of a patient. At last, records about the general condition of the patient are collected as well as the cause of admission, the patient’s relevant history and the time being in the hospital. There is especially attention to the factors that increase the risk at developing decubitus.

**Computer modeling**

The intention was to make a computer model in order to predict the mechanical response of the separate soft tissue layers in the human while lying or sitting in bed. A similar model is made by Oomens et al., 2003. The model may be used as an addition to the clinical data. Unfortunately this was not possible because of several reasons. Prior to the training period the subject of my project was still unknown. Thus there was no time to prepare well the training period in the Netherlands. Secondly, the right software was not available in Kenya. And at last, it would take several months in the Netherlands to obtain data from the model.

### 3.4.3 Results

**Risk assessment**

Table 3.4 shows the parameters of the risk assessments that have a great influence on the risk of developing pressure ulcers. The table shows that the percentages for the number of people older than 65 years is about 15%. A great percentage of the patients is bedridden and completely immobile in bed (no) or bedridden and able to turn in bed (no). The completely immobile patients had indeed applied traction. Together their number is almost 35% of the population. When looking at shear stresses, taking the patients that have or have little shear stresses together, more than 35% experience shear stresses in such way that it increases the risk of developing pressure ulcers. Few patients have or have little neurological diseases.

<table>
<thead>
<tr>
<th>Age (%)</th>
<th>Ambulant (%)</th>
<th>Shear stresses (%)</th>
<th>Neurological diseases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age&gt;65</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>1</td>
<td>21,7</td>
<td>17,4</td>
<td>4,3</td>
</tr>
<tr>
<td>2</td>
<td>8,3</td>
<td>8,7</td>
<td>30,4</td>
</tr>
<tr>
<td>3</td>
<td>16,7</td>
<td>13,6</td>
<td>13,6</td>
</tr>
<tr>
<td>4</td>
<td>12,5</td>
<td>33,3</td>
<td>8,3</td>
</tr>
<tr>
<td>Average</td>
<td>14,8</td>
<td>18,27</td>
<td>14,18</td>
</tr>
<tr>
<td>Std</td>
<td>6,8</td>
<td>4,4</td>
<td>13,2</td>
</tr>
</tbody>
</table>

**Prevalence**

The averaged number of patients at Lucas ward was 21: from these were 35% discharged in. The ratio between men and women amounts to 3:2. From all patients 13,5% developed pressure ulcers; 87% of all pressure ulcers was developed in the hospital. There was just one woman that developed pressure ulcers. In comparison to other periods in a year the number of patients was lower but relatively more patients were discharged in. Moreover, more patients were victim of road accidents then usual.

**Observations**

Seven patients between the 25 and 91 years were observed with an averaged age of 60 years. One of them was a female. 57% of the patients were older than 65 years. If each area around a bone attachment is a location as well as each buttoc, then there are 13 bedsores in all. Some examples are shown in Figure 3.x. All of them are classified in stages: 5 wounds at stadium II, 5 wounds at stadium III and 3 at stadium IV. Two patients had bedsores at several locations. All patients, except one, had bedsores near the sacrum; two of them had also bedsores at both trochanters. One patient had decubitus at the backside of his thighbone due to the position of the applied traction. Necrotic tissue was present in 5 wounds over 4 patients; this was twice black, dry necrotic tissue and the other times yellow. Also granulation tissue was present 5 wounds over 3 patients. Yellow tissue was visible in 5 wounds over 4
patients. The sizes of the ulcers were very variable between a diameter of 2 cm up to a diameter more than 10 cm.

Figure 3.3. From left to right: a fourth grade pressure ulcer on a buttock of a patient with a hip injury, fourth grade ulcer with black necrotic tissue just removed in theatre all over the buttock of a paralyzed woman, a fourth grade pressure ulcer at the trochanters of a patient with spinal tuberculosis.

The causes of admission to the hospital were spinal tuberculosis (1x), femur fracture (3x), pelvis fracture (1x), underleg fracture that resulted in amputation (1x), and total misery including severe anemia, paralyzed lower limbs, malnourished: this was due to neglecting after road accident (1x). All men stayed for more than 8 weeks in the hospital, the women has to go home after 2 weeks. Except for the women all stayed in the hospital until the medical officer discharged them.

3.5 Discussion

From the patient study it has become clear that several patient groups are at high risk to develop decubitus; elderly people, patients that need traction after a bone fracture, paralyzed people, patients with spinal tuberculosis (this also means traction) and patients that have had an amputation. Children are less vulnerable to the disorder. Those who are recovering from an operation are almost never at risk. If a patient is in traction or is paralyzed, he will be certainly bedridden for the long-term. Many of these patients are even not able to turn in bed by themselves due to corporal restriction or physical restrictions because of the traction construction. In addition, pressure sores heal slowly in any case. Nevertheless, it is not common that patients are admitted to the hospital for a longer period because of the pressure sores. Thus wound treatment can only be controlled by staff during the time of being admitted. What can be said about the wound treatment? In general the nurses do their job very well and pay much attention on it. When looking at cleansing especially, povidone should not be used anymore in the case of bedsores in the future. In the case of debridement it is proven that sharp and surgical debridement are the most appropriate. In addition the current dressings still meet all requirements with the cheap, available gauzes and strapping and moreover, will not cause any increase in running costs in the future. However, near the sacrum these gauzes hardly remain intact and hence, the use of triangular dressings is preferred above the usual rectangular dressings at that place.

In order to stimulate the healing of pressure ulcers the hospital could think about applying electrical stimulation techniques. Some advantages are that the technique is safe, relatively easy to apply, and that costs of applying are low. Because the hospital already possessed an electrical stimulator, although broken down, it is also simple to introduce to the hospital. The technique would be most effective at patients that are certainly admitted to the hospital for a long time such as patients in traction. From literature it is known that the best results are achieved at grade III and IV wounds. In addition, the patient study showed that there is evidence for this because a great part of the observed pressure ulcers were classified as grade III and IV. But the therapy should be done frequently, this means more than once a week, otherwise there will be no results.

Furthermore, remarks can be made about the risk assessments. In general current risk assessment techniques, such as visual inspection and risk assessment scales, mainly focus on skin and may underestimate the risk of deep sores. A similar focus is observed in the hospital. This has also a relationship with the knowledge level amongst the nurses. In fact, the only practical purpose of risk assessment is to identify persons at risk and to facilitate the development of a plan of care. If nurses are able to identify persons at risk, they become less independent of the knowledge of higher staff and it would be easier for them to estimate the best treatment. The results of the risk assessments done for this patient study demonstrate that there is a high risk to develop pressure ulcers in particular among older men. The most important factors seem to be age, shear stresses and reduced mobility. Neurological diseases can be seen as inferior, probably due to the fact that this disease is seen more in more common wards. Furthermore, the skin condition may influence the risk of developing ulcers. This parameter is
discussed many times because it is hard to determine the skin condition. Can a skin look at not being dry without the use of moisture lotion? Drinking water, eating fruits, and so on could influence the skin condition as such as the general condition of an individual. From a European opinion one would agree but this will not be hold by the averaged Kenyan man. Nevertheless, it is observed that the hospital staff does have a less dry skin than the averaged patient. Therefore, more attention to drinking sufficient water and ensure a balanced diet is advocated in general. Additionally a more balanced diet is recommended in any case in order to stimulate the healing process of pressure sores and the patient’s other diseases.

In order to prevent pressure ulcers pressure relief is very efficient. Financially it is not realistic to think about new mattresses and beds. In order to improve the prevention of decubitus it should therefore be advisable to have more lifting devices, bed sheets with elastic at the margins, more cushions and blankets, and more attention to repositioning. Because wind rings are worldwide dissuaded and may transfer infections among patients, it would be better to use cushions or blankets instead of wind rings to release the pain. If the patient and his relative are involved in the dialogue about treatment, the healing process will be stimulated. Informative posters at the ward could inform the patient and his relatives about the disorder and especially about pressure relief and wound treatment. As an example relatives may bring cushions or blankets from home; on one side this helps to relief the pain, on the other side the running costs are kept low.

The analyses of pressure relief also resulted in new devices that are designed during the research. There was just one lifting device available and few beds were adjustable. In order to fulfill the wish of more lifting devices a wooden lifting device was designed together with the hospital’ workshop as just as a wooden adjustable bed. The drawings can be found in Appendix C, the first example in the ward can be seen in Figure 3.4. The advance of these materials is that they can be made in the workshop of the hospital and that the materials are very cheap in comparison of steel.

Thus, it could be concluded that many patients are at high risk to develop pressure ulcers. And indeed, the prevalence is quite high. In reality mostly men have pressure ulcers and these are mainly located around the sacrum and the buttocks. For pressure relief there is still a lack of devices like cushions, lifting devices and adjustable beds. Although more lifting devices has become available on the ward. Latex gloves and wind rings should absolutely not be used anymore for prevention. On the other side it should be not a good idea to change the wound treatment too many, because the current method seems to be good and the cheapest. However, electrical stimulation can be introduced in the treatment in order to stimulate the healing process. And lastly, it can be concluded that attention to other factors such as a nutritional diet, skin condition is necessary in the treatment and prevention of pressure ulcers. In general the higher risk patients can be more easily identified with the assistance of a risk assessment scale and a plan of care could help to achieve the goals of the treatment.

![Figure 3.4: The first wooden lifting device in use at Lucas ward.](image)
4 Femur fractures at young children

4.1 Introduction

4.1.1 Aim and outline
In this study femur fractures due to a traumatic incident are observed. Fractures due to a traumatic incident are caused by sudden and excessive force. If it is a direct force, the long bone will break at the point of impact. Surrounding soft tissues also must be damaged. Tapping usually causes a transverse fracture and damage to the overlying skin; crushing is more likely to cause a comminuted fracture which means that the bone is broken into more than two bone fragments. If it is an indirect force, the bone will break at a distance from where the force is applied. Soft tissue damage at the fracture site is not inevitable. The type of fracture depends on the applied force: twisting causes a spiral fracture, bending causes a transverse fracture, a force that include bending and compressing results in a fracture that is partly transverse but with a separate fragment, a combination of twisting, bending and compressing causes an oblique fracture, and pulling forces pulls the bone apart. The main objective of this study is to investigate when an adjustment in the treatment belonging to femur fractures at young children is wishful. And also, would it be realistic to apply another method than traction or to adjust the rehabilitation process? Again the study begins with some theoretical background followed up by current methods. Theoretical background is necessary to classify the fractures in the patient study and to recognize the traction techniques. Current methods include also the admission procedure as well as the current traction techniques that are in use. In the patient study patients younger than the age of seven and with a femur fracture are observed in the hospital in order to analyze the applied traction and the current rehabilitation process and to find out the disadvantages of this treatment. Furthermore, a literature study should be done to investigate the possibilities to implement another method then traction and to invent how the rehabilitation process can be improved. Due to a lack of information during the training period this was not possible like mentioned before.

4.1.2 Natural healing process after fracture
This paragraph can be seen as some additional information for a better understanding of the treatment of femur fractures. The described healing process is according to a tubular bone like the femur in the absence of rigid fixation. Healing proceeds in the next five stages, i.e. tissue destruction and haematoma formation, inflammation and cellular proliferation, callus formation, consolidation and remodeling.

Tissue destruction and haematoma formation
Vessels are torn and a haematoma forms around and within the fracture: there is tissue damage and bleeding at the fracture site. Bone at the fracture surfaces, deprived of a blood supply, dies back for a millimeter or two.

Inflammation and cellular proliferation
Within 8 hours an acute inflammatory reaction appears with cell proliferation under the periosteum and within the breached medullary canal. Through surrounding cellular tissue the fragment ends are bridged. The clotted haematoma is slowly absorbed and fine new capillaries grow into the area.

Callus formation
The proliferating cells will start forming bone under the right condition and in some cases cartilage. The cell population changes to osteoblasts and osteoclasts. Osteoclasts begin to mop up dead bone. The thick cellular mass, with its islands of immature bone and cartilage, forms the callus (or splint) on the periosteal and endosteal surfaces. Callus serves to stabilize the fragment as rapidly as possible and ensures mechanical strength while the bone ends heal. As the immature fiber bone or woven bone becomes more densely mineralized, movement at the fracture site decreases and at four weeks after injury the fracture unites. Clinically union means that the fracture site is still a little tender and, though the bone moves in one piece, attempted angulation is painful and it is not safe to subject the unprotected bone to stress.

Consolidation
The woven bone is transformed into lamellar bone due to continuing osteoclastic and osteoblastic activity. The system is now rigid enough to allow osteoclasts to burrow through the debris at the fracture line, and close behind them osteoblasts fill in the remaining gaps between the fragments with new bone. This slow process may take several months before the bone is strong enough to carry normal loads. Clinically consolidation means complete repair. The fracture site is not tender anymore and further protection is unnecessary.
Remodeling
This stage begins after the fracture has been bridged by a cuff of solid bone. That region is reshaped for months, or even years, due to a continuous process of alternating bone resorption and formation. Especially in children the bone reassumes something like its normal shape. Thicker lamellae are laid down where the stresses are high; unwanted buttresses are carved away; the medullar cavity is reformed.
To predict the duration of the entire healing process depends on many factors like age, constitution, blood supply, and type of fracture. Therefore the time to unite and to consolidate may vary according to each person and each fracture.

4.2 Theoretical background

4.2.1 Specifying place and type of a fracture
Although there are many variable types in appearance, the types of fractures can be divided into complete and incomplete fractures mainly. A complete fracture means that the bone is completely broken into two or more fragments. Complete fractures can be subdivided in transverse, oblique, spiral and impacted. They differently act after reduction. If the fracture is transverse, the fragments remain in place usually; if it is oblique or spiral, the fragments tend to slip and redisplace in any case. In an impacted fracture the fragments are jammed tightly together and the fracture line is indistinct. Due to poor interlocking of the fracture surfaces a comminuted fracture is often less stable than a simple fracture. An incomplete fracture has the characteristic features that the bone is incompletely broken and the periosteum remains in continuity. In children a greenstick fracture can be seen: the bone is buckled or bent. The other incomplete fracture is called compression fractures and these are not common in children.
Müller’s classification is in use to specify the place and type of a fracture along a long bone like the femur (Figure 4.1). Each bone has three segments: proximal, diaphyseal and distal. The type of diaphyseal fractures may be specified as simple, wedge or complex. Proximal and distal fractures can be more specified as extra articular, partial articular or complete articular.
After a complete fracture the bone fragments usually become displaced due to reasons like the force of injury, gravity and the attached muscles that are pulling. Displacement is usually described in terms of apposition, alignment, rotation and altered length.
Apposition (shift): fragments shifted sideways, backwards or forwards in relation to each other. Fracture surfaces lose contact. Usually unite. Shift can be sideways, overlap or impaction
Alignment (tilt): fragments tilted or angulated in relation to each other. If uncorrected, deformity of the limb.
Rotation (twist): fragment rotated on its longitudinal axis. Bone looks straight but the limb ends up with a rotational deformity.
Length: Distracted and separated or overlap due to muscle spasm causing shortening of the bone

4.2.2 Different traction techniques
According to the book Primary Surgery the advised treatment of fractures of the central part is as follows. At birth there is no treatment necessary in general. Shaft fractures should be treated with Gallows traction or a plaster spica for children till three years. Children older then three years get

Figure 4.1: Müller’s classification of femur fractures. (Source: Primary Surgery, p. 303)
extension traction. A last method could be the Perkins’ traction, but this is usually done with adults. For this type of traction the foot end of the bed is usually elevated as counterforce. The related limb can be elevated as well but this is mainly done to vanish a swelling. Depending on the type of fracture, the child age and the applied technique the traction has to be applied 1 till 5 weeks. It should be obvious that in most cases rehabilitation is necessary because the loss of muscle and junction function. Although children like to play and often begin rehabilitation by themselves, physiotherapy is necessary in some cases.

4.3 Current procedures

4.3.1 Admission procedure
When a patient is admitted to the hospital, there is a standard form to fill in. The procedure is only written down in the case of a fracture. The form begins with personal records. The next page is more specified. Firstly, the history has to be described: what has been the cause of admission? Next, general signs are described like looking pale or not, is the patient ill or not and so on. Then the physiotherapist has to fill in the local signs in the case of a fracture: he does a palpation and describes what he notices around the fracture. So he determines if the fracture is open or closed and collects records about the surrounding soft tissues. Further a patient with a femur fracture always needs an X-ray when admitted. This X-ray gives additional answers to the palpation: which bone or bones are broken, is a joint surface involved, what is the shape of the break and what kind of dislocation? Furthermore, there could always be secondary injuries. For instance, fractures of pelvis may be associated with visceral injury.

4.3.2 Treatment of closed femur fractures at young children
In general the applied traction techniques are conform the Primary Surgery book. St Mary’s Hospital prefers the Gallows traction above a plaster spica for shaft fractures at children till 3 years. The cots in the hospital have a frame to apply Gallows traction. Most children stay in the ward for 1 till 5 weeks depending on the type of fracture and individual factors. If they become discharged, physiotherapy will begin within a week. The physiotherapy often begins in the ward because there is mostly a delay in paying the bill and hence, the patient has to stay in the hospital. Many patients need crutches. These wooden crutches are made in the workshop and have a standard design. Only the patients’ length is variable and therefore the length from heel to armpit is measured. This length corresponds with the length of the crutches. The position of the handgrips is always at one third in length from the armpit. The surface under the armpit is well padded.

4.3 Patient study

4.3.1 Aim
As mentioned children belonging to the target group for this patient study are children at the orthopedic ward, which are both younger than seven years and has a femur fracture. The first objective of the patient study is to investigate which traction techniques are actually applied and what are the results of this technique. The second objective is to analyze the efficiency of the current rehabilitation process. Unfortunately, it was not possible to collect sufficient and reliable statistics for the second objective, due to the fact that none of the children were in the physiotherapy department. Although most patients already had the first physiotherapy in the ward one week after removing the traction, this process could not be followed after they paid the bill and returned home, because the patients did not return to the hospital for physiotherapy exercises.

4.3.2 Methods
Demographic characteristics of the patient are copied from the admission chart just as the information about the fracture collected during admission. The healing process and the treatment are followed during the time being in the hospital by means of doctors’ notes, physiotherapists, nurses and the patient. Also the X-rays are analyzed. An overview of important parameters can be found in table 4.1. Again it was not possible to measure the body weight. However, the age could be used to estimate the weight of an averaged child in Kenya with the next formula

\[ \text{Weight (kg)} = 1.4 \times \text{Age (years)} + 3.4 \]
Weight (kg) = (Age + 4) x 2

Table 4.1: Parameters measured during the patient study.

<table>
<thead>
<tr>
<th>Age</th>
<th>Date of fracture</th>
<th>Reduction</th>
<th>Total weeks of bed rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sexe</td>
<td>Admission date</td>
<td>Shortening of broken leg?</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>Type of fracture</td>
<td>Sexe</td>
<td></td>
</tr>
<tr>
<td>Body weight</td>
<td>Traction weight</td>
<td>Pin placement</td>
<td></td>
</tr>
<tr>
<td>General condition</td>
<td>Accident</td>
<td>Position of patient</td>
<td></td>
</tr>
</tbody>
</table>

4.3.3 Results
Seven patients were observed: five of them had broken the shaft of the femur with a fragment often shifted, one had a slipped epiphyses and another one had an anterior dislocation of the hip. All children under 3 years had Gallows traction in a cot. There was one exception: this child came some weeks after traditional healing to the hospital and went home with plaster. Two children above the three had skin extension traction; the last one had a pin traction.

It was easy to consider the X-ray after the accident as well as after the reduction. In most cases the next X-ray was taken just before the child went home. Therefore, it was not possible to consider the last X-ray because mostly the child took the X-ray home. Thus it is hard to get some idea about the success of the traction for the long-term. It is unknown in most cases how the bone was united and the remodeling process could not be followed as well. However, all children could easily walk with crutches after the extension traction.

4.5 Discussion
Most children broke the shaft of the femur. All children had a treatment following Primary Surgery and went home on crutches. All equipment, although sometimes improvised, were available. No information became available about consolidation and remodeling of the bone because the last X-rays taken could not be considered. All children went home on crutches and did not return for rehabilitation. The reason for that could be the extra costs or that there was no need for it.

The current treatment is good and cheap and do not need any adjustments. It is difficult to conclude anything about the need of an alternative technique due to a small number of patients within the study and the lack of information about alternative techniques. More research should also be done in order to investigate why children do not return to the hospital for physiotherapy exercises.
5 Conclusions

Both studies took place on the orthopedic and surgical ward of a district hospital in Kenya. The aim of the pressure ulcer study was to investigate the state of the treatment and prevention of pressure ulcers. In the current situation there is no special attention to prevention although patients at high risk are regularly repositioned or get sink oxygen crème to protect vulnerable skin at bone prominences. The risk assessments showed that many patients have a risk developing pressure ulcers. The average prevalence is 13.5%. From the 13 observed pressure ulcers there were 5 ulcers classified at stadium II, 5 at stadium III and 3 at stadium IV. The wounds are well-dressed every day. Some adjustment in pressure relief could be more cushions or blankets to support, more lifting devices and no use of wind rings anymore. Another adjustment to improve the circumstances of the patient could be a more balanced diet. It is important that all medical staff and the patient and his relatives are well informed about the treatment.

The aim of the femur fracture study was to analyse the current treatment and to investigate if it would be wishful to introduce another techniques in the hospital. The patient study showed that most children under 7 years had a shaft fracture. All children were treated in accordance with the instruction book. No information was available about the consolidation and remodelling of the bone. All children did not return to the hospital for rehabilitation. There is no evidence from this small-scale study that any adjustment in the current applied traction method is necessary and for the second part in the process, the rehabilitation, no children could be observed. Due to a lack of theoretical information during the study the alternative techniques for the current applied traction could not be investigated.
6 Evaluation

My training period had clearly an additional value to my study. I experienced the period as very informative as well as fascinating. I have seen and done things like I never did before and probably would never do again. There were two factors apparently different from most other training periods at BME: firstly, the set up was in a developing country and secondly, the training period was oriented more practically than usual. This combination has given me more understanding in the field of biomedical engineering.

I actually felt being involved at Lucas ward. This is enjoyable but may also help in doing research. Although it was difficult to find the balance between assisting the physiotherapist in his daily activities and doing research. The collaboration with the physiotherapist and the nurses was very good. The physiotherapists taught me a lot of skills involving putting plaster and applying traction. I really enjoyed that! I also had a good communication with my supervisors from the university, with thanks to the e-mail connection of the hospital.

I find out that it is hard for me to ask time from hard working staff. Perhaps I should have done that more times. Another fact I learned about myself that I found it hard to motivate myself because no one else would do that for you in the hospital. It is great to have so many freedoms in doing your research and that everyone wants to help you but every step you take has to begin at yourselves. My supervisor is a very busy man; he is surgeon, doctor like other and medical officer in charge. Thus he was not able to spend much time to my study unfortunately. A good idea for a next student would be to discuss the progress of the research more often then I did because this will stimulate the progress.

I wish to have more and better results. Unfortunately this was not possible due to several reasons. There was no preparation possible in the Netherlands because the subject was not known yet. Another struggle was that I had to wait for receiving theoretical background information after I knew the subject. Furthermore, an introduction period of three weeks was necessary to know each other, i.e. the hospital has to be introduced to the possibilities in the field of biomedical engineering and vice versa, and to find out the possibilities for research in the hospital. If the subject were known before arrival, it would have been easier for the student and the hospital to begin with the research and there would be more time to do research. Thereby it would have been possible to focus on a less clinical topic and more on an engineering topic. Also there were less patients towards Christmas. As a consequence no new patients relevant for both studies came in during the last weeks of my training period. Thus the season could influence the number of patients studied. Lastly, in the beginning I focused more on the femur fracture study. Later on, the emphasis lied on pressure ulcers because more literature was available and more topics could be involved in the study like dressing the wounds but also the state of materials and designing new materials during my time being in the hospital.

From the final meeting with my supervisors, the surgeon and both physiotherapists, it became clear to me that not only the lifting device I designed was relevant for the hospital but also the other aspects of the study. Together we had a fascinating discussion about which parts of my results the hospital could use for improvements in the future.

At last, I would like to say that I am convinced that a training period at St. Mary’s Hospital is very suitable for students of biomedical engineering or any other hospital in a developing country. It is absolutely instructive and fascinating to the student. However, good supervising as well as the adaptability of the student to the environment are required to come to good results for both the hospital and the university.
References


11. Primary Surgery,

12. St Mary’s Hospital, year report 2002, Mumias, Kenya, 2002


Appendix A: Introduction Period

Week 1: Physiotherapy
This week my supervisors were the physiotherapists. I had an introduction to their activities at Lucas ward, the physiotherapy department and the outpatient department. They taught me some basic skills. Soon I understood that the physiotherapists are orthopedists too. They taught me how to reduce bone fractures, to put plaster and to apply traction in that field. At the physiotherapy department they taught me about different treatments, especially for stiff joints after an injury.
We discussed about orthopedic devices, pressure ulcers, applying traction, the treatment of bone fractures at young children, and so on. Long-term orthopedic devices cannot be made in the hospital and are too expensive for the patients in common. Another threshold is that the patient has to travel to Nairobi to try the device. Most patients from this rural area have never been to a big city like Nairobi before. There is sufficient material available in the hospital to apply traction. The reason that they choose traction instead of a surgical procedure including the use of pins is the running costs for the patient. The surgeon can do that action but again, it is too expensive for the patient. The physiotherapist had an obviously wish to improve the treatment of pressure ulcers and bone fractures at young children. It also seems to be the most realistic to improve at these fronts. Therefore, these two options were chosen as possible object for a research study.

Week 2: Maternity and Administration

Administration
Firstly, for the hospital administration it is desirable to improve the financial system. An important challenge will be the change from a manual to a more digital system. Unfortunately for the hospital, this has not any relation with biomedical engineering despite the computer skills I broad from Europe. Nevertheless, during my stay I tried to assist as much as possible when there were troubles with the computers.

Maternity ward: I had my introduction though the sister in charge and the doctor. They show me around on the ward, in particular they show me all devices from the incubator till the ultrasound scope. They involved me at the doctor’s round at the ward. I also saw deliveries but indeed, I was just an observer. Maternity ward possesses two incubators, which are made through the KTI, Amsterdam. Normally the babies lie together with the mother in a bed on the ward. The incubators are meant to give babies more chance to survive through lying in a controlled and sterile environment in a special room. Temperature and air pressure can be regulated by using water, a lamp and electricity. The incubators do not work but according to the sister in the charge it is also not necessary to make them work. Therefore, this is dropped out as possible project. Another technical problem has to do with the vacuum pump. The nurses are afraid to use the pump, because it is not clear what the used scaling is and how it is possible to calibrate the pomp. This would be a more practical project and therefore, after my complete introduction period I concluded that there were no possible projects for me to do at Maternity.

Week 3: Theatre/ anesthesia
Although the surgeon was not present that week, this week was a very interesting one. The anesthetist was my supervisor and also the theatre nurses taught me some skills. The most important skill they taught me was to cut and fold the gauzes for all wards, which they do when they are waiting. The anesthetist showed me around in theatre. Together we installed an ECG apparatus from the stalls in Room 1. At this moment Room 1 is the best equipped and is just like Room 2 sterile. The third room has no advanced equipment. I saw operations like leg amputation, finding an intestinal obstruction and Caesarian section. All (electrical) equipment is donated and if this equipment becomes defective, there is no technician available with the right skills to repair.
During surgeries the anesthetist is responsible for controlling certain body functions of the patient. The most important physiological parameters to monitor include blood pressure, heart rate, respiration, temperature, blood flow, and oxygen saturation. A short overview of the kind of equipment includes monitoring systems like ECG, oxygen supplies, anesthetic machines, suction machines, diathermy, and adjustable tables. It is not easy to improve the controlling functions. Important factors include the costs of the purchase, maintenance, and use. Also the skills of the anesthetists are important. It is desirable that the anesthetists can solve some technical problems and have the know-how about the physics behind the system. In this case a research project could be to make it possible for the anesthetist to control all the physiological parameters as mentioned above.
### BRADEN SCALE FOR PREDICTING PRESSURE SORE RISK

<table>
<thead>
<tr>
<th>Patients Name</th>
<th>Evaluator Name</th>
<th>Date of Assessment</th>
</tr>
</thead>
</table>

#### SENSORY/PERCEPTION

- **1. Completely Limited**
  - Unresponsive to pain or pressure
  - No way to respond to verbal commands
  - Pain sensation not present
  - Unable to respond to pressure

- **2. Very Limited**
  - Responds to verbal commands
  - Pain sensation not present
  - Unable to respond to pressure

- **3. Slightly Limited**
  - Responds to verbal commands
  - Pain sensation present
  - Able to respond to pressure

- **4. No impairment**
  - Responds to verbal commands
  - Pain sensation present
  - Able to respond to pressure

#### MOISTURE

- **1. Constantly moist**
  - Skin is constantly moist
  - Exposed to moisture
  - Skin is occluded

- **2. Very moist**
  - Skin is moist
  - May be changed at least once a day

- **3. Occasionally moist**
  - Skin is occasionally moist
  - Change is needed

- **4. Rarely moist**
  - Skin is rarely moist

#### ACTIVITY

- **1. Bedrest**
  - Bedrest

- **2. Chairrest**
  - May sit in a chair

- **3. Walks occasionally**
  - Occasional walking

- **4. Walks frequently**
  - Frequent walking

#### MOBILITY

- **1. Completely immobile**
  - Cannot move without assistance

- **2. Very limited**
  - Limited mobility

- **3. Slightly limited**
  - Limited mobility

- **4. No limitation**
  - Mobility is complete

#### NUTRITION

- **1. Very Poor**
  - Eats less than half of meal
  - Needs feeding
  - Needs tube feeding

- **2. Poor**
  - Eats half of meal
  - Needs feeding

- **3. Adequate**
  - Eats meals
  - No feeding tube

- **4. Excellent**
  - Eats all meals

#### FRICTION & SHEAR

- **1. Problem**
  - May slide

- **2. Potential problem**
  - May slide

- **3. No apparent problem**
  - Able to move

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Total Score
Appendix C: Lifting device and adjustable bed.

Figure C.1: The left figure shows a possible position of the wooden adjustable bed together with the lifting device. In the right picture the fixing to the bed can be seen. The lifting device is tied together with ropes to the bed.