Monitoring of patients prescribed potassium supplements

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Introduction: In Northern Ireland, clinical technicians have been supporting pharmacist in their work in over five decades. From initially having mainly administrative tasks, the role of pharmacy technicians has progressed to more clinical activities. Following recent incidents caused by inadequate monitoring of potassium blood levels it was suggested pharmacy technicians could be utilized to improve patient care.

Aim: Aim of this project was to ensure the appropriate monitoring and compliance with treatment guidelines for patients prescribed potassium supplements by extending the role of pharmacy technicians at Antrim Area Hospital.

Methods: Training for extending the roles of clinical technicians was developed, following the structure of a regional training programme. Literature search was made to find appropriate background about the subject of interest. Data about monitoring of potassium levels in the relevant patients was collected. Daily monitoring of these patients before and after the change was implemented were compared.

Results: Clinical technicians contribution to monitoring of patients prescribed potassium replacement therapy improved guidelines compliance from 66.6 % to 90 % ($x^2$-test, $p = 0.028$). Percentage of successful treatment raised from 66 % to 89.7 % ($x^2$-test, $p = 0.028$).

Conclusion: By extending roles of the clinical technicians, better and appropriate monitoring of patients prescribed potassium supplements can be reached. In future, roles of the pharmacy technicians could be extended further, thus releasing pharmacists time to expand their role, leading to a more cost-effective system and ensuring medicines optimization.
Populärvetenskaplig sammanfattning

Klinisk farmaci i Nordirland expanderar. Genom att kliniska farmaceuters kompetens och användningsområdet utvecklas, kan även farmaceutiska teknikernas roll utvecklas. Farmaceutiska tekniker har hjälpt och stött kliniska farmaceuter i över 50 år. Från början hade de mest administrativa uppgifter, men på senare tid har teknikerna även börjat arbeta mer kliniskt. På grund av tidigare rapporterade incidenter hos patienter som behandlades med kaliumtillskott, där behandlingsrekommendationer för behandling av hypokalemia inte följdes och patienterna hade potentiellt utsatts för skada hade apotekstekniker tack vare deras kunskap och förmåga föreslagits att bidra till dessa patienters behandling.

Genom detta projekt fick farmaceutiska tekniker en lämplig utbildning som behövs för att förstå innebörden varför patienter får kaliumtillskottbehandling och hur deras blodvärden tolkas. I resultatdelen jämfördes följsamhet med riktlinjerna för behandling av hypokalemia innan involvering av farmaceutiska tekniker med följsamhet med riktlinjerna då apotekstekniker blev involverade.

Metoddelen bestod alltså av 3 delar, fasen innan förändringen, fasen där apotekstekniker fick sin utbildning och fasen där apotekstekniker aktivt bidrog till övervakningen av patienter förskrivna kaliumtillskott. I första fasen observerades 30 patienter, om deras kaliumvärde var taget dagligen och även utfallet av behandlingen. Träningsprogrammet för teknikerna följer strukturen för regionalt träningprogram och bestod av inläsning-bakgrunden om hypokalemia och riktlinjerna som ska följas vid behandling med kaliumtillskott, introduktion till laboratoriesystemet samt fallstudier. När apoteksteknikerna blev klara med utbildningen observerades 30 patienter som behandlades med kaliumtillskott där teknikerna aktivt såg till att riktlinjerna följdes och provtagning av deras kaliumvärde beställdes dagligen.

Resultatet visade att genom involvering av farmaceutiska tekniker ökade följsamhet med riktlinjerna från 66,6 % till 90 % ($x^2$-test, $p = 0,028$). Ur resultatet kunde även observeras att antal behandlingstillfällen som blev lyckade och hade ett positiv utfall ökade från 66 % till 89,7 % ($x^2$-test, $p = 0,028$).

Sammanfattningsvis kunde det observeras ur resultatet från detta projekt att genom involvering av apotekstekniker i behandlingen av patienter som behandlas med kaliumtillskott, en bättre följsamhet med riktlinjerna och även utfallet ur behandlingskuren kan nås. I framtiden kan apotekstekniker utvidga sin roll och kompetens ännu mer. Liknande träningssprogram kan implementeras på andra områden, t.ex. INR-värde observation hos warfarinpatienter.
Introduction

Background

In Northern Ireland, a programme named Integrated Medicine Management (IMM) has been implemented and shown successful outcomes since 2000 (1–3). The IMM services involves the systematic provision of medicine therapies through a partnership of effort between patients and healthcare professionals to deliver best patient outcomes and minimise cost. The reason for establishing this programme was problems including medicine management, such as adverse drug reactions, wastage of medicines and lack of compliance with prescribed medicines (1). Optimisation of the medicines process by this program has led to benefits to patients in terms of morbidity and mortality, reduced readmissions and reduction in length of hospital stays (2,3).

Role of pharmacy technicians

Despite the established role of pharmacists as part of health care system and expanding of the scope of pharmacy, there are obstacles remaining which hinder the optimal delivery of pharmaceutical care. These include increasing complexity of medication regimes and most significantly the shortage of pharmacist (4–6). In order to maintain optimal pharmaceutical patient care but at the same time give pharmacists the possibility to enhance their clinical services, the roles of pharmacy technicians needs to extend (4). Pharmacy technicians have been supporting the work of pharmacists for over five decades. Their traditional role was initially more administrative, such as performing inventory control and dispensing prescription (6,7).

In recent years pharmacist have transformed their practice to provide more clinical activities, and thereby they needed to redeploy their technical duties to pharmacy technicians enabling the pharmacists to focus on optimal patient care and optimize medicine therapy (6). To achieve effective and well-functioned pharmacy service in hospitals and health systems, the role of pharmacy technicians needs to extend and appropriate education must be available.

Currently, in Northern Ireland there is a well establish education programme for pharmacy technicians, Medicine Management Accredited Programme (MMAP) (8). The MMAP is designed to develop and extend the skills and competences of clinical technicians delivering medicines management roles within clinical environment. MMAP consist of pre-course activities, in- practice activities, holistic observations and development of pharmacy technician’s own portfolio to evidence of developing of competence.

Extended role of pharmacy technicians

Multiple studies have demonstrated that trained pharmacy technicians were just as effective as pharmacists and others health care professions, in some of the services that
pharmacists provides (6,9–12). This includes taking medication history and administering immunisation vaccines. Irwin and others (11) qualitative review demonstrated that when obtaining the medication histories, pharmacists and pharmacy technicians identify a greater number of discrepancies than physicians and nurses. When comparing pharmacists with pharmacy technicians in obtaining medication histories, the study showed that pharmacy technicians are capable of identifying medications discrepancies and medication history with a similar level of accuracy as pharmacists. In another study (6) administration of immunisation vaccines by pharmacy technicians were studied. When appropriate education was provided (13), pharmacy technicians were capable of administration of vaccines with zero adverse events reported. This was a pilot program in Idaho, and after successful outcome, in March 2017 pharmacy technicians became legally allowed to administer the immunizations vaccines for the first time (6,12). There is another factor that is important to consider when pharmacy technicians roll extends. Since health care organizations and hospitals are in lack of resources of pharmacists, to the standard workflow and have focus on optimal and safe medication, pharmacy technicians represents a more cost-effective alternative to ensure appropriate pharmacy services and relieve pharmacist from technical and administrative duties (11).

Currently, there is a drive to empower pharmacy technicians with more independency and responsibility to provide a greater contribution to patient care (6,14). The pharmacy department at the Queen Elizabeth Hospital (QEH) have been extending the roles of pharmacy technicians for over a decade to support the clinical pharmacy services. Integration of technicians into health care teams make it possible to extend their role within following setting: medical admission ward (medical history), inpatient medical wards, discharge planning teams, medicines information and even on anticoagulant clinics. Clinical technicians also have an important role in identifying adverse drug reaction, which requires appropriate clinical knowledge and good analytical and decision-making skills. Integration of technicians also contribute to faster review of drug history. Audits on QEH have shown that over 90 percent of patients admitted to medical ward have been reviewed by the pharmacy team within one working day. At the anticoagulation clinic, that is a pharmacy-led facility, pharmacy technicians are fully involved in delivering clinical services. Audits on QEH examining the national standard in anticoagulation clinic services, have shown that there has been no reduction in quality of clinical services given by pharmacy technicians in comparison with clinical services given by pharmacist. Clinical technicians at this clinic are trained to calculate warfarin doses, identify patients who require changes to anticoagulation medication and identifying side-effects that may be caused by anticoagulation treatment (14).

**Pharmacy technician’s referral of patients to pharmacist**

To facilitate the extended roles of the pharmacist, roles of clinical technicians need to be extended as well. As many studies and programmes demonstrated, integration and extending the role of pharmacy technician benefits the clinical services and health care system (6,9–11,14). Currently, in Antrim Hospital, the pharmacy technicians are referring to pharmacists based on patients’ medications, as prescribed on the hospital
prescription and administration record (Kardex). Pre-set criteria are used in referral system, to make the pharmacy team more efficient and helps prioritize the referrals and interventions that need to be made. The criteria are divided into a traffic light colour system, where “red” means inform the pharmacist on ward immediately, “amber” represents record on whiteboard in pharmacist’s room and “green” means endorse the medicine prescription and administration record. The “red” referrals includes allergy status not/ incorrectly documented, inappropriate administration times, inappropriate route/formulation/dose or duplication of product. The “amber” includes referrals as patient prescribed high risk drug or switch of IV/oral antibiotics. The pre-set criteria was developed in 2013 and evaluation of them showed increased number of inpatient intervention (15).

In this project, clinical technicians at Antrim Are Hospital, will be able to record blood results in patients prescribed potassium supplements to enable appropriate monitoring of potassium levels. Monitoring of patients treated with potassium supplements is included in the “amber” referrals according to the pre-set criteria system and these patients need to be monitored closely.

**Importance of potassium**

Potassium plays an important role in maintaining the cell function (16,17). Almost all cells in human body possess an Na⁺-K⁺-ATPase pump that generate an ion gradient between intracellular and extracellular compartment. Na⁺-K⁺-ATPase pump pumps Na⁺ out of the cell and K⁺ into the cell and thereby is potassium one of the most abundant cation in the intracellular fluid (16). Potassium’s gradient across the cell membrane (K⁺\textsubscript{in} > K⁺\textsubscript{out}) is essential to the function of the cell, mainly in excitable tissue, all vascular and neuromuscular excitations, contractions and conductions. Levels of potassium that are too high or too low impair the function of these tissues, in particular cardiac muscle and nerves. The normal total concentration of K⁺ should be approximately 50 mmol/L. Ninety eight percent of the total K⁺ concentration is within cells (intracellular) and only two percent outside the cells (extracellular). It means that in the extracellular fluid the normal concentration of K⁺ should be approximately 3.5 to 5.3 mmol/L. Deviations from normal serum concentration can cause harm to cells and impair the cell function (17).

Because of the importance of a stable potassium gradient level, the human body has developed a mechanism to maintain normal K⁺ serum concentration. Primarily responsible for homeostasis of K⁺ concentration are kidneys. However, the kidney has a relatively slow ability to excrete the potassium, that occurs over several hours. That is why, when potassium loads (intake of a potassium rich meal) it is initially moved into cells, until the kidney reestablish the total amount of potassium. This is a mechanism that prevents rises of potassium in the extracellular compartment. Most important physiological factors regulating this movement of potassium into the cell are insulin and beta-adrenergica (16). Therefore, after a meal intake, insulin is released to not only regulated the serum glucose from the meal but also shift the movement of potassium into cells, until the kidney reestablishes the normal potassium level and excretes the
overload. The beta-adrenergic regulation plays a role during exercise. Under normal circumstances, exercise results in movement of intracellular potassium into the interstitial compartment of the skeletal muscle. The accumulation of K+ in the interstitial compartment of the skeletal muscle induce a vasodilation and thereby allows increase in blood flow and higher muscle perfusion during the exercise. However, this mechanism is multifactorial, and exercise also activates the autonomic nervous system and helps maintain the serum potassium. These were the main physiological factors regulating the potassium levels, but gastrointestinal tract also plays a minor role as well, which can be observed in patients that lose kidney function. In these patients contribution of the gastrointestinal tract increases and up to half of the potassium secretion may occur in the colon (17,18).

There are many factors that can disrupt potassium serum levels and electrolyte balance (16,19). The most common factors include medication errors, which can lead to development of both hyperkalemia and hypokalemia.

**Hypokalemia**

Hypokalemia is defined as a condition (19–21), when serum potassium concentration is below 3.5 mmol/L (19). Hypokalemia can cause harm to patients and be life-threatening. Most affected tissues, when potassium is in imbalance are muscles and kidneys (renal tubular cells). It has a linkage to cardiac arrhythmia, myocardial infarction and cardiac arrest. Most vulnerable patients for these complications, are the patients with cardiovascular disease (20). Hypokalemia has also connection to severe neuromuscular dysfunction such as generalized muscle weakness, urinary retention, paralytic ileus, rhabdomyolysis and acute renal failure (21). Patients who are suffering from hypokalemia have longer hospital stays and higher in-hospital mortality risk than normal inpatient population (19). Development of hypokalemia is often multifactorial. Most common factors are medication errors and errors in preparations of intravenous fluids (inappropriate electrolyte content) and these factors can be preventable.

Medications that are decreasing the potassium levels and should be flagged are: loop and thiazide diuretics, penicillin, antibiotics including penicillin, aminoglycosides and beta-agonists. There are studies that suggest, that hypokalemia was more commonly developed in patients that were using these drugs and beyond that, were the elderly patients, patient with low serum concentration of albumin and magnesium (19–21). Underlying hypomagnesemia can often be a reason to developing hypokalemia. Studies have shown that more than 50% of clinically significant hypokalemia has concomitant low magnesium serum levels and can be most frequently observed in patients prescribed loop or thiazide diuretics (22). There are some risk factors that have in general low prevalence but are strongly associated with electrolyte imbalance and development of hypokalemia, including Cushing’s syndrome, aldosteronism, adrenal adenoma or carcinoma which often results in increased mineralocorticoid activity and disrupt potassium serum concentrations. These were the risk factors for development of hypokalemia, but on the other side, there are some protective factors as well. Patients who were taking potassium-increasing drugs including angiotensin converting enzyme (ACE) inhibitors, angiotensin II receptor blockers (ARBs), potassium sparing diuretics...
and nonsteroidal anti-inflammatory drugs (NSAID) had a lower risk of development of hypokalemia and instead had higher risk of development of hyperkalemia (16,19).

Hyperkalemia

Etiologies for hyperkalemia are often a result of a combination of intrinsic and extrinsic factors (16,23). Extrinsic factors includes medications that increase potassium serum concentration and were mentioned earlier (ACE inhibitors and ARBs, NSAID and potassium saving diuretics), but they also include external potassium intake such as potassium supplements and potassium rich diet. Potassium supplements are prescribed to patients who have had low potassium serum levels and the potassium levels need to be observed (21,23). Common intrinsic factors are decreased glomerular filtration rate, selective reduction in distal tubule secretory function, decreased distal delivery of sodium, impaired mineralocorticoid activity and metabolic disturbances such as hyperglycemia and acidemia. Increased prevalence of common chronic diseases including diabetes mellitus and chronic kidney disease makes hyperkalemia more frequent. Hyperkalemia is defined as a potassium serum concentration greater than 5.3 mmol/L and just like hypokalemia can be a life-threatening complication if it is not treated. Most vulnerable patients are patients with underlying chronic kidney disease. Two of the most serious conditions caused by hyperkalemia are development of malignant arrhythmias and increased risk of development of ventricular fibrillation that are associated with increased short term death rates in patients both with and without chronic kidney disease (16). Because of these serious complication, it is important that patients prescribed medication therapy with potassium supplements, ACE inhibitors and ARBs have regular monitoring of their serum potassium levels (16,21).

Guidelines for treating hypokalemia

To secure optimal patient care and give appropriate treatment when patients have hypokalemia, treatment guidelines for potassium replacement therapy must be followed. At Antrim Area Hospital there is an internal policy issued by the Northern Trust which is due for review. The aim of this policy is to provide a guideline for the management of short-term hypokalemia in adults. Critical parts of the guideline’s issues:

- Patients on potassium replacement therapy must have their blood results done at least daily and have potassium recorded with prescription altered as appropriate.
- Prescription length of maximum 2-3 days of oral potassium replacement therapy and have written stop date on Kardex.
- Appropriate dose of potassium supplement depending of severity of hypokalemia
- Check magnesium levels before initiating the potassium replacement therapy treatment
Incidents when potassium levels were not monitored appropriately

At Antrim Area Hospital, there have been recently reported incidents where unmonitored potassium levels in patients taking potassium supplements led to serious complications and could have caused harm to patient. Two incidents will be described below.

Patient 1:
Patient was prescribed 24 mmol oral potassium supplement for treatment of hypokalaemia. Treatment’s length should be 3 days, and doctor on the wards had prescribed “For 3 days” but not-specific stop date on the medicine record. The patient received an extra three days treatment of potassium supplement and when blood results were taken in the end of the treatment, they showed potassium levels above normal range. Patient required treatment for hyperkalaemia.

Patient 2:
Patient was commenced on oral potassium supplement 20 mmol four times a day with no stop date prescribed. Treated patient was during the treatment transferred to another ward in the hospital. On the new ward patient´s blood results were not checked over a weekend period. On Monday, after weekend, pharmacist reviewed potassium levels following referral from pharmacy technicians and patient was found be hyperkalaemic and required treatment.

Potassium levels outside normal range can cause serious complication to patient and thereby patients prescribed potassium supplement need to be monitored. These two incidents were examples of the reported cases where guidelines for treatment of hypokalaemia were not followed. Followed complications and potential harm to patients shows the need of better compliance of treatment recommendation´s, appropriate monitoring of potassium levels and raise the need of this project. These incidents were the cause and new opportunity to utilize skills and knowledge of pharmacy technicians to contribute to a more optimal patient care.

Aim

Aim of this project was to ensure the appropriate monitoring and compliance with guidelines treatment recommendations of patients prescribed potassium supplements by extending the role of pharmacy technicians at Antrim Area Hospital
Methods

Wards

The wards chosen for the data collection were ward B2 with 27 beds and ward B3 with 35 beds at the Antrim Area Hospital. B2 is the endocrinology ward and B3 takes care of cardiac patients. These two wards were chosen because they have patients staying for a longer time which makes it possible to observe the patients and because on these two wards, there are many prescriptions of potassium supplement.

Data collection

A data collection sheet for collection of the pre-intervention phase data was developed and is presented in Appendix 1. The sheet collected information on route of administration of the potassium supplement, what dose patients were prescribed, if the prescription followed the guidelines for potassium supplement therapy and if patients’ are taking any others medication than can cause hyperkalemia. It also collected information about frequency of reporting of potassium level for patients taking the potassium supplement and the blood result. The sheet was presented to senior pharmacist, Linden Ashfield, and tried out on randomly chosen ward, ward B4 one work day prior to start of the data collection. Following discussion with the senior medical consultant responsibility for clinical pathology, if the patient had their magnesium level checked when hypokalemia was diagnosed was also recorded.

Analysis time-line

The project started by meeting with senior pharmacist, Linden Ashfield on Monday, 4th of February. The need for this project because of earlier incidents, caused of the insufficient monitoring of potassium, were highlighted and the aim of this project was formulated. On the same afternoon meeting with two researchers from the Medicines Optimization Innovation Centre (MOIC) were arranged to discuss the methodology of this project. The project was divided to 3 different parts:

- Pre-intervention phase
- Training programme
- Post-intervention phase

Following week, commencing on 11th of February, pre-intervention phase data collection started and were ongoing in 4 weeks, until 30 patients on potassium supplement were identified and data analyzed. When data for pre-intervention phase were collected, training for the pharmacy technicians started. Summarized training programme pathway is described in Figure 1. During clinical technicians training programme, questionnaire for pharmacist were sent out and answers collected. After finished clinical technicians training programme and their final interview, collecting of post-interventions data started. Post-interventions data were collected in a
period of 3 weeks, until 30 patients of potassium supplement were identified and analyzed.

Training programme

The training programme pathway is summarized in Figure 1. The training programme structure followed structure of Medicine Management Accredited Programme (MMAP) for education of clinical technicians. Clinical technicians chosen for this project required to be a senior pharmacy technicians.

READING AND LEARNING

FIRST INTERVIEW

LOG OF 20 RESULTS (DOUBLE CHECKED BY PHARMACIST)

THREE CASE STUDIES

FINAL INTERVIEW AND FEEDBACK FROM MENTOR

Figure 1. Training programme pathway.

Technicians training started with reading. Literature research was made, to find appropriate background about the subject of interest on appropriate level for clinical technicians and based on found findings, Standard operating procedure was developed. Reading consists of 4 parts:

- Background reading about potassium and magnesium (The Fluid and electrolyte balance, see Appendix 2)
- Potassium Guidelines of Northern Health and Social Care Trust
- Instruction on use of internal laboratory system BSO
- Standard Operative Procedure (SOP) (see Appendix 3)
After reading and learning phase, technicians had their first interview with senior pharmacist Linden Ashfield. During this interview there were able to reflect about what they have learned and get feedback from mentor. See the template for interview in Appendix 4. When approval from mentor was given to clinical technicians, they were able to start their Log of 20 potassium levels, which were double check by pharmacist, to ensure reliability. Template for collection of potassium levels is attached in Appendix 5. After finished Log of 20 results, clinical technicians had to describe 3 different Case Studies. Case Studies were structured to give ability to reflect about possible causes of needed treatment and how the treatment worked, see template for In-practice Case Studies in Appendix 6. Following successful completion of this stage of the training programme, clinical technicians had their second- final interview. In this interview technicians discussed their learned skills and how they will apply them in medicine management role. Feedback from mentor was given. See Appendix 7 for final appraisal interview template. When the clinical technicians met the standard in relation to final interview, they were able to start with potassium monitoring and record blood results on their own. Standard operating procedure for regular daily monitoring of blood results of patients treated with potassium replacement therapy by clinical technicians was developed, see Appendix 8, and the project continued to post-intervention phase.

Inclusions criteria

Patients included in this project must fulfil these criteria:

- Patients treated with oral or intravascular potassium replacement therapy
- Are adult patients (age >16 years 9 months)

Questionnaire

To achieve an objective overview about compliance of the potassium replacement therapy guidelines recommendations, of the daily monitoring of blood results of potassium levels, an anonymous questionnaire for pharmacists was developed. Questions asked included main issues, if when blood labs are taken, if pharmacist actually look them up and actively monitor the potassium levels of patients taking potassium supplement, see Appendix 9. Other questions included in questionnaire were frequency of patients treated by potassium supplement on different wards and awareness of potassium replacement therapy guidelines. The Questionnaire was sent out to pharmacists at Antrim Area Hospital during technicians training programme phase, to minimize potential bias on pre-intervention phase data.

Statistical analysis

The results from Pre-intervention and Post-intervention data collection were summarized and analyzed in Excel. To decide, what statistical analyses is suitable,
consultation with a teacher from Uppsala University was made. Chi-square tests were used because of testing of the relationship between categorical variables. Tutorials on YouTube showing how to use Excel, to do the statistical analyses were used. Chi-Square test were suitable to answer questions of the study:

- Did the number of patients that have their potassium levels monitored daily during treatment with potassium replacement therapy differ in Pre-intervention and Post-intervention phase? ($\alpha = 0.05$)
- Did the number of succeeded treatments with potassium replacement therapy differ in Pre-intervention and Post-intervention phase? ($\alpha = 0.05$)
- Did the number of patients that had not their potassium levels monitored during weekends differ before and after pilot? ($\alpha = 0.05$)

**Ethical approval**

On meeting with MOIC on Monday 4th of February the need for ethical approval for this project was discussed. It was decided that this study didn’t need an ethical approval by using a decision tool from the National Health Service (24) as recommended by MOIC, because this study is considered as service improvement.
Results

Guidelines compliance of daily monitoring of blood results of patients on potassium replacement therapy

In the Pre-intervention phase, 30 patients on potassium replacement therapy were studied. The guidelines recommendation compliance of daily blood results monitoring was analyzed and is summarized in Figure 2. The results showed, that in 20 patients (66.6%) the treatment policy was followed as recommended. Ten patients (33.3 %) did not have their blood results monitored daily during their treatment. In seven patients of the total ten who had not had their blood results monitored daily as recommended, the missed blood results occurred during weekends.

Pre-intervention data were compared with Post-intervention data, that is summarized in Figure 3. Of total amount of 30 patients, the guideline recommendation was followed in 27 (90 %) patients. Clinical technicians ordered blood results during treatment of 12 (40%) patients, which released other health-care providers. Three patients of the total 12 did not have their blood results done until next day of the treatment and their blood levels had not been monitored every day during their treatment. None of the missed potassium levels monitoring occurred during weekends. Summary and comparison of Pre-intervention data and Post-intervention data is pictured in Figure 4.

Monitoring of patients treated with potassium replacement therapy improved and significant difference could be observed after clinical technicians’ training and their involvement in potassium monitoring ($x^2$-test, $p = 0.028$). The number of missed daily monitoring of patients’ potassium levels decreased from 10 to 3 treatment occasions. There is a significant difference when, either during weekends or work days, missing of the daily monitoring of potassium levels occurred ($x^2$-test, $p < 0.001$). Before the pilot, most of the patients, 70 %, had not their labs done daily occurred during weekends. After the pilot, none of the missed labs during potassium replacement therapy treatment occurred during weekends.
Figure 2. Summary of the Pre-intervention phase of the daily monitoring of blood results of patient treated with potassium replacement therapy and compliance of Trust’s policy.

Figure 3. Summary of the Post-intervention phase of daily monitoring of blood results in patients treated with potassium replacement therapy and compliance of Trust’s policy.
Potassium replacement therapy effects

Treatment outcomes with potassium replacement therapy was analyzed and is summarized for both Pre-intervention phase and Post-intervention phase in Figure 5. In this analysis only short-term treatments with potassium supplements were considered and the one patient on long term potassium was excluded. During Pre-intervention phase, in 10 of total 29 (34%) patients’ treatment with potassium supplements was not successful and their K⁺ levels were not stabilized when treatment finished. Four of these patients had not their magnesium levels done, despite Guidelines recommendation of checking magnesium levels before initiating the potassium replacement therapy. Six patients had their magnesium levels monitored and in two of total six patients the magnesium levels were low. None of the patients with low magnesium levels got treatment for hypomagnesaemia. The Post-intervention data collection showed that the treatment with potassium supplements was not successful in 3 patients. Only one of these patients had his magnesium levels checked before initiating potassium replacement therapy. Improvement of the number of successful therapies with potassium supplements could be observed. The number of successful treatments raised from 66 % (before pilot) to 89.7 % (after pilot) (x²-test, p =0.028).
Guideline compliance with writing the Stop date on Kardex

Potassium replacement therapy guideline recommendation compliance was analyzed in its second regard- if stop date is written on Kardex, when patient is prescribed oral potassium supplement. Results are summarized in Figure 6. In this part of project, guidelines recommendation compliance was compared between involved wards, B2 and B3 and total summary of compliance of writing up stop date on the Kardex is added as well. Oral potassium supplements were prescribed in 54 patients. In 37 patients (68.5 %) the Stop date on Kardex was written and the Trust policy were followed in this point. Seventeen of total fifty-four patients (31.5%) had no stop date on their Kardex written. On cardiology ward, B3, the Trust policy were followed in 60 % of patients, in 18 of total 30, treated with potassium supplement therapy during data collection period. On the endocrinology ward, B2, compliance of the Guidelines was higher, 79.2%. Stop date on Kardex was written in 19 of 24 cases.
Figure 6. Summary of compliance of Guidelines recommendation for patients treated with oral potassium replacement therapy, regarding having Stop date written on the Kardex.

Guidelines compliance of monitoring magnesium level before initiating the potassium replacement therapy

Guidelines recommendation compliance was analyzed in next regard- if magnesium level was checked before initiating therapy with potassium supplements. Comparison between involved wards, B2 and B3, and the total number of treatments that followed the Trust policy in this point, are summarized in Figure 7. In total number of 60 patients, treated with potassium replacement therapy, both oral and intravascular, 29 patients (48.3 %) had their magnesium levels check before initiating therapy with potassium supplements. Ward B3 had a better compliance of the Trust policy in this regards. Magnesium levels were checked in 17 of total 32 patients (53.1 %) on the cardiology ward. Ward B2 have magnesium levels monitored in 12 of total 28 patients (42.9 %) before initiating the therapy with potassium supplements.
Answers from questionnaire

Of the 11 pharmacists invited to answer the questionnaire, 9 participate. All of participated pharmacists answered that they were familiar with the Trust policy for management of hypokalemia in adults. To the question about treatment frequency of patients on potassium supplements, four participants answered that they have patients on potassium replacement therapy daily and five participants answered “few times a week”. Answers about how often pharmacists actively monitor potassium levels are summarize in Figure 8. Only one participating pharmacist answered “Always” monitoring the potassium levels. Four participants were monitoring the blood results most of the time during treatment and 2 participants respectively monitor the potassium levels about 50 % and occasionally (≤ 25 %). Five of the eight pharmacist who do not monitor the blood results as the Trust policy recommends stated that the reason is mainly lack of time.

Figure 7. Summary of the Trust policy compliance in point-checked magnesium level before initiating treatment with potassium replacement therapy.
Figure 8. The frequency of actively monitoring of potassium levels by pharmacists participating in questionnaire.
Discussion

Questionnaire

As the results from questionnaire had shown, all participating pharmacist are familiar with Trust policy and treat patients on potassium replacement therapy either daily or at least few times a week. To follow the Guidelines, patients on potassium supplements must have their blood labs be done at least daily and have potassium recorded with prescription altered as appropriate. Potassium supplement is classified as a high risk drug (amber color classified in referral system) and potassium levels of treated patients need to be both done and monitored at least daily.

Because of the earlier mentioned incidents, the hypothesis was, that the potassium levels are not monitored as guidelines recommend. Only one participating pharmacist answered that the monitoring of blood results is done daily. This answer could be affected by the knowledge of pharmacist that they should be monitoring labs daily. Eight of nine participating pharmacist did not monitor as Trust policy recommends, which reflect the reality more accurate (results are summarized in Figure 8). Reason to not check the blood results, was mainly lack of time, 5 of 8 answers, 62.5 %. To prevent missing of compliance of the Trust policy and ensure appropriate monitoring of patient on potassium replacement therapy utilization of clinical technicians seems to be a solution.

Intervention affected outcomes

Clinical technicians are an important part of pharmacy team and they are showing an interest of doing more clinical work. Pharmacist must often prioritize referrals classified as “red” and often monitoring of other patients falls behind. As many other studies have shown (6,11,14) extending roles of clinical technicians and giving them more independency provide a great contribution to patient care to more cost-effective alternative.

During the Post-intervention phase, clinical technicians made sure, that in 12 patients, during their treatment with potassium replacement therapy, labs were ordered for next day and for weekends. In 3 of the total 12 cases, the labs were missed anyway. When discussing this with technicians, labs were requested, but the laboratory could not deliver results until next day. These results came in all three cases early morning on the day after the request was made. Referring back to the two patients, mentioned in the introduction, this new process would minimize the chance of these incidents happening. By extending pharmacy technicians roles, after the pilot, the number of missed blood results during weekends decreased from seven to zero. Technicians made a request in advance of weekends, in which patients labs must be done and thereby ensured appropriate monitoring of these patients. Most of the earlier reported incidents where not appropriate monitoring of potassium levels had been made, caused harm to patients occurred during weekends.
There is often a shortage of pharmacist, clinical technicians and other health-care providers on weekends which could contribute to these outcomes. Therefore, to have clinical technicians ensuring ordering of the labs on weekends better and appropriate monitoring can be reached. Before the pilot, there was not a specific health-care provider that made sure that the labs were ordered. In the Post-intervention phase, it is still not specified which health-care provider should make a request for the labs, but clinical technicians are set to monitor the potassium levels, and if no labs are ordered for next day, they will request them.

From the results from Post-Intervention phase, as expected-could be observed that a better monitoring of blood results contributes to more successful outcomes of potassium replacement therapy. Intervention made by this project, allowed and ensured active daily monitoring of potassium levels and contribute to catch differential outcomes of the treatment earlier. These differential outcomes include:

- Patients’ potassium levels raised before treatments’’ Stop date”
- Patients’ potassium levels were not stabilized when treatment was about to end

Clinical technicians catch these different outcomes and made sure that the patients were reviewed and had their treatment adjusted. Technicians released other health-care providers from these duties, save their time, and made sure that patients will get more appropriate monitoring thus optimizing their treatment.

**Guidelines compliance**

Pharmacy technicians were in this project set to daily monitor potassium levels and make sure that the labs are ordered. From the results it could be observed that this intervention affected the number of patients that had their potassium levels monitored every day (raised from 66% to 90 %), monitoring of blood results during weekends and number of successful treatments.

Interventions made in this project only affected one point from the Trust policy recommendations, that “Patients on potassium replacement therapy must have their blood results done at least daily and have potassium recorded with prescription altered as appropriate”. None of the other points included in the Trust policy were affected by this intervention. This could be even observed from results about monitoring magnesium levels before initiating the potassium replacement therapy or having written stop date on Kardex, which did not differ significantly before and after the pilot.

Data about prescribed dose were not collected during this project. Ward B3, is a cardiology ward and would be expected to have relatively good compliance with the Guidelines. Many patients on B3 have indication for potassium replacement therapy and staff working on this ward are familiar with this indication. Despite the frequency of potassium supplements prescription, the Guidelines were not followed. Compliance of checking magnesium levels before initiating the potassium replacement therapy was only 53.1 % and compliance of having written stop date was 60 %. On the endocrinology ward they had better compliance of having written stop date on Kardex,
79.2 \% but a worse in monitoring of magnesium levels before initiating therapy with potassium supplements, 42.9\%.

Reasons for these observations could be many, but number of junior doctors with less experience could be one of them. This could be reduced by presenting the results of this project at medical training and providing education to junior doctors by pharmacists including sending out reminders about the Trust policy frequently. Another way to improve compliance with the Guidelines, could be to extend clinical technicians’ roles even more and have them request magnesium levels as well.

Future views

From the results of this project, it has been shown that by extending clinical technicians’ roles, appropriate and improved monitoring of patients receiving potassium supplementation can be reached improving patient safety. In this project, because of the earlier mentioned incidents, potassium monitoring was chosen, but the training programme developed, can be applied to many others extended roles. As mentioned earlier, monitoring of other electrolytes, that are crucial in different treatments could be part of the clinical technicians extended rolls. This could include magnesium levels monitoring for treatment of hypomagnesaemia or hypokalemia, monitoring of calcium levels hypocalcemia and many others. Similar training procedures could be applied when monitoring patients prescribed warfarin and their INR-levels or in monitoring renal function.

Limitations and strengths

One limitation of this project could be a bias on collected data. This might be caused by the knowledge about this project among the staff. Before initiating collection of data, project was discussed with staff working at the hospital. This could affect the prescriptions of potassium supplements, monitoring of potassium levels and compliance with the guidelines and give more positive results then the reality is.

During the project, suggestions about what data should be collected and might be of interest raised and the data collection sheets were adjusted to be different between pre-intervention phase and post intervention phase. These adjustments limited the ability to compare all data collected. The size of this project was too small to alone be significant even though many interesting findings were detected.

On the other side, regarding to the specific indication and patients group required for this project, the obtained results, despite the size of the project can be considered as a significant, at least on the local level. Another finding and strength of this project was, that by a well-build training programme given to skilled and willing health-care providers, in this case pharmacy technicians, better compliance with guidelines and improved treatments outcomes can be reached.
Conclusion

In conclusion, results from this project shows that by extending roles of the clinical technicians, better and appropriate monitoring of patients prescribed potassium supplements can be reached. Despite the knowledge among staff about recommendations of the Trust policy, compliance with guidelines is low. Lack of time and awareness have been stated as the main reasons.

With greater contribution of clinical technicians to the patient care, better outcomes from potassium replacement therapy could be observed. Daily monitoring of patients’ blood results raised from 66 % to 89.7% and monitoring of potassium levels during weekend increased to 100%. In future, clinical technicians’ roles can be extended even further, to relieve pharmacist from some of their responsibilities, in more cost-effective system to ensure medicines optimization.
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Appendices

Appendix 1. Baseline data collection form

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<th>Potassium Supplement</th>
<th>Magnesium Supplement</th>
<th>Dose Guidelines Y/N</th>
<th>Stop date on Kardax</th>
<th>K⁺ levels Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
<th>Mg²⁺ level</th>
<th>Other drugs causing Hyperkalaemia (ARBs or ACE inhibitors, potassium saving diuretics, NSAID)</th>
<th>Notes</th>
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Training programme
Appendix 2. Fluid and electrolyte balance

**FLUID & ELECTROLYTE BALANCE**

**POTASSIUM DISTRIBUTION IN THE BODY**

The total amount of potassium in the body is 3000mmol. The normal serum range is 3.5-5mmol/L. As with sodium it is extremely important in the correct functioning of excitable cells such as muscles, neurones, sensory receptors, etc. About 10% of body potassium is found in red blood cells, bone marrow and brain tissue and is not exchangeable. The remaining 90% is free and exchangeable with most being located in the ICF (intracellular fluid). Only 2% of exchangeable potassium is in the ECF (extracellular fluid) and this is the compartment from which the serum sample is taken. Consequently, the measurement of serum potassium is not an accurate index of total body potassium but together with the clinical condition of the patient it indicates any problems involving potassium homeostasis.

The serum potassium concentration is controlled mainly by the kidneys with the gastrointestinal tract having a minor role. The potassium filtered in the kidney is almost completely reabsorbed in the kidney in the proximal tubule. Maintenance of potassium levels is connected to sodium metabolism. Sodium reabsorption by aldosterone is usually in exchange for hydrogen or potassium ions. This is a passive process in response to maintaining membrane potential neutrality and is associated with reabsorption of sodium in the distal convoluted tubule and collecting duct. Thus, high levels of potassium in the ECF, stimulates aldosterone which increases sodium reabsorption in the kidneys and in turn potassium excretion, returning the level of potassium in the ECF to normal. The extent of potassium secretion is determined by:
- The amount of sodium available for exchange in the distal convoluted tubule and collecting duct
- The amount of hydrogen and potassium ions for exchange in the distal convoluted tubule or collecting duct
- The ability of the distal convoluted tubule or collecting duct to secrete hydrogen ions
- The concentration of aldosterone
- Tubular flow rate

Both potassium and hydrogen can neutralise the membrane potential generated when sodium is reabsorbed and consequently there is a close relationship between potassium and hydrogen ion homeostasis. In acidosis, hydrogen ions are normally secreted in preference to potassium and potassium is reabsorbed (hydrogen ions are excreted making the serum pH less acidic and potassium is retained leading to increased serum potassium level). In alkalosis, hydrogen ions are reabsorbed in preference to potassium ions and potassium is excreted (hydrogen ions are retained making the serum pH more acidic but there is decrease in serum potassium as it’s excreted).

**Hypokalaemia** is a low potassium serum level, under 3,5 mmol/L. The main causes are:

- Transcellular movement of potassium from ECF to ICF – the shift of potassium from the serum compartment of the ECF into cells accounts for the hypokalaemia reported following intravenous or nebulised B2 agonists such as salbutamol. Parenteral insulin also causes a shift of potassium into cells and is used for this purpose in the treatment of a high potassium serum level.
- Loss from the gastrointestinal tract – although potassium is secreted in gastric juice, much of this together with the potassium ingested in the diet, is reabsorbed in the small intestine. Stools do contain some potassium, but in a patient with chronic diarrhoea or a fistula, considerable amounts of potassium may be lost and precipitate hypokalaemia. The abuse of laxatives also increases gastrointestinal potassium loss and may precipitate hypokalaemia. The potassium secreted in gastric juice may be lost in the case of persistent vomiting and also contribute to hypokalaemia.
- Loss from the kidneys – Minaralocorticoid excess, whether it be due to primary or secondary hyperaldosternism or Cushings syndrome, can increase urinary potassium loss and cause hypokalaemia. Likewise, increased excretions of potassium can result from renal tubular damage – nephrotoxic antibiotics, such as gentamicin have been implicated in this.

The patient with moderate hypokalaemia may be asymptomatic. The symptoms of more severe hypokalaemia include:

- Muscle weakness
- Hypotonia
- Paralytic ileus
- Depression and confusion
• Arrhythmias
• Increased blood glucose – potassium is required for normal insulin secretion in response to rising blood glucose

Hypokalaemia is managed by giving either oral or intravenous potassium, depending on its severity.

Many drugs which can induce hypokalaemia do so by affecting the regulatory role of aldosterone upon potassium/sodium exchange in the distal tubule and collecting duct. Administered corticosteroids can mimic aldosterone and can increase potassium loss. The most commonly used drugs which can cause hypokalaemia are thiazide (bendroflumethiazide) and loop diuretics (furosemide, bumetanide). Both groups of drugs increase the amount of sodium delivered and available for reabsorption at the distal convoluted tubule and collecting duct. Consequently this will increase the amount of potassium excreted from the kidneys.

### Drugs known to cause Hypokalaemia

<table>
<thead>
<tr>
<th>Drug</th>
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<tbody>
<tr>
<td>Amphotericin</td>
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<td>Aspirin</td>
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<td>Corticosteroids, e.g. prednisolone</td>
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<td>Diuretics, e.g. Bendroflumethiazide</td>
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<td>Gentamicin</td>
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<td>Glucose</td>
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<td>Insulin</td>
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<td>Laxatives</td>
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<td>Salbutamol</td>
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<tr>
<td>Terbutaline</td>
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<td>Piperacillin + Tazobactam</td>
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<tr>
<td>Sodium bicarbonate</td>
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<td>Benzylpenicillin</td>
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</table>

**Hypermkalaemia** is a high serum potassium level, over 5.0 mmol/L. It may arise from excessive intake, decreased elimination or shift of potassium from ICF into the ECF. The inappropriate use of parenteral infusions containing potassium is probably the most iatrogenic cause of excessive intake. Hyperkalaemia is a common problem in patients with renal failure due to their inability to excrete a potassium load. The combined use of a potassium-sparing diuretic, such as amiloride, triamterene or spironolactone (aldosterone antagonist) with an ACE inhibitor which will also lower aldosterone by blocking renin-angiotensin system (causing potassium reabsorption in
preference to sodium), is a recognised cause of hyperkalaemia. Mineralocorticoid deficiency states such as Addisons disease where there is a deficiency of aldosterone (potassium will be reabsorbed in preference to sodium) also decreases renal potassium loss and contributes to hyperkalaemia.

The majority of body potassium is in the ICF. Severe tissue damage, catabolic states or impairment of energy dependant sodium/potassium pump, caused by hypoxia or diabetic ketoacidosis, may result in hyperkalaemia due to potassium moving out of and sodium moving into the ICF.

Hyperkalaemia can be asymptomatic but fatal. An elevated potassium level has many effects on the heart – the membrane potential is lowered, and action potential shortened. Characteristic changes of the electrocardiograph (ECG) precede ventricular fibrillation and cardiac arrest.

In emergency management of a patient with severe hyperkalaemia, intravenous calcium gluconate is given – this does not lower the potassium but antagonises the effect of hyperkalaemia on the cardiac tissue. Immediately after, glucose with insulin is given by infusion – this causes a shift of potassium from ECF to ICF which lowers serum potassium levels. If acidosis is present, bicarbonate may be given.

The long-term management of hyperkalaemia may involve the use of oral or rectal polystyrene cation-exchange resins which remove potassium from the body, e.g. calcium resonium powder –these bind with potassium in the gut creating a molecule which is too big to be absorbed and is then excreted. It is usually given rectally as it works faster.

Foods with high potassium content:
- Bananas
- Nuts
- Chocolate
- Crisps

Chronic hyperkalaemia in renal failure is managed by a low potassium diet.

### Drugs known to cause Hyperkalaemia

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<td>ACE inhibitors e.g.</td>
<td>ramipril</td>
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<td>Angiotensin II</td>
<td>Receptor blockers</td>
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<td>e.g. Irbesartan</td>
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<td>NSAIDs e.g.</td>
<td>Ibuprofen</td>
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<td>Beta blockers, e.g.</td>
<td>bisoprolol</td>
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<td>Ciclosporin</td>
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<td>Digoxin (in acute</td>
<td>overdose)</td>
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<td>Potassium sparing</td>
<td>diuretics -</td>
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<td>Lithium</td>
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<td>Penicillins (potassium salt form)</td>
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<td>Potassium supplements</td>
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<td>Tetracycline</td>
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Appendix 3. SOP

SOP

Aim
To ensure Potassium monitoring in patients prescribed oral and intravenous potassium by extending the role of technicians.

Scope
This procedure will be aimed at senior clinical technicians.

1. Identify patients on oral/ i.v. potassium supplement
2. Check if stop date has been documented on Kardex. If no stop date, or stop date ≥ 3 days, refer to pharmacist.
3. Record patients details on Potassium monitoring log (Appendix)
4. Log in to BSO lab system as per “Instructions on how to look- up results on BSO system for clinical staff”.
5. Enter patient H+ C numbers and hit search.
6. Select U + E from the list.
7. Enter relevant Potassium result into Potassium monitoring log.
8. Check if a Magnesium level has been analysed and record magnesium level on monitoring log.
9. Following check ensure blood samples has been requested for the following day (for 2 days for weekend).
Appendix 4. Pre-course Reflective Log

Pre-course Reflective Log

Candidate name: Date:

- Module 1 - The Fluid and electrolyte balance
- Module 2 - Potassium Guidelines
- Module 3 - Instruction on use of BSO laboratory system

Pre-course reading:
Did you read the Potassium treatment guidelines and fluid and electrolyte balance?
Yes □ No □

How will you use this learning within your medicines management role?
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Feedback from mentor
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Candidate signature:_____________ Educational supervisor signature:_____________
Date:________________________ Date:________________________
## Appendix 5. Log of 20 patients

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<th>Number</th>
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<th>HCN</th>
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<th>Mg²⁺ level</th>
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Appendix 6. In-practice Case Studies

In- practice Case Studies

No 1. □ No 2. □ No 3. □

Candidate name: Date:

Briefly describe the scenario to include, possible cause of hypokalemia and prescribed treatment for replacement. Any other medications that could cause increase or decrease in potassium level? Reflect about length of treatment. Did treatment work? Was magnesium level taken?

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Comments/suggestions from Educational supervisor:

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Candidate signature: Date:

Educational supervisor signature: Date:
Appendix 7. Final Appraisal Interview

Final Appraisal Interview

Candidate name: Date:

Recording of laboratory results

Interview to include discussion of following: Yes or No

- Procedure for undertaking potassium management role
- Strategies for maintain focus on a busy clinical/ward environment
- Provide example of one thing that you have learned from undertaking this course
- Did the candidate make any errors during the programme? Ask candidate to reflect on these

Interview notes and feedback to candidate:

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

Has candidate mett standard in relation to final appraisal interview? Yes □ No □

Candidate signature: Date: Educational supervisor signature: Date:
Appendix 8. SOP

SOP : To request and record blood levels of potassium for patient’s prescribed potassium supplements

Introduction:
Due to the risks involved with potassium supplementation it is important that patients’ blood potassium levels are monitored closely. The Trust policy NHSCT/17/1081 ‘Potassium Guidelines: Treatment guidelines for potassium replacement in hypokalaemia in adults’ states that ‘U&E to be done at least daily and K+ recorded with prescription altered as appropriate’.

Aim
To ensure Potassium monitoring as per Trust policy in patients prescribed oral and intravenous potassium by extending the role of technicians.

Scope
This procedure is for senior clinical pharmacy technicians who have successfully completed the relevant training programme.

1. Identify all patients on oral/ intravenous potassium supplementation as per clinical pharmacy SOP: CLIN/19/64 Senior Pharmacy Technician Clinical Review of Prescription and Administration Record (Band five).
2. Check if stop date has been documented on Kardex. If no stop date, or stop date greater than 3 days, refer to pharmacist.
3. Record patients details on Potassium monitoring log (Appendix 1)
4. Log in to BSO lab system as per “Instructions on how to look- up results on BSO system for clinical staff”. Appendix 2
5. Enter relevant Potassium result into Potassium monitoring log. (if result is 2.5 or less or 6.5 or greater also inform the pharmacist immediately).
6. Check if a Magnesium level has been reported and record magnesium level on monitoring log.
7. Following check ensure blood sample has been requested for the following day (for 2 days for weekend).

April 2019
Appendix 9. Questionnaire for pharmacist

Pharmacists Survey regarding Hypokalaemia

This is anonymous survey. Please leave your completed survey in the folder in clinical room.

Please select the option below that corresponds best with your reflection

1. How often are patients prescribed potassium supplements on your ward?
   - □ Daily
   - □ Few times per week
   - □ Few times per month

2. Are you familiar with the Trust policy for management of hypokalaemia in adults?
   - □ Yes
   - □ not sure
   - □ No

3. Do you check the potassium level every day of all patients on your ward prescribed potassium supplements?
   - □ Always
   - □ Most of the time (>75%)
   - □ about 50%
   - □ occasionally (<25%)
   - □ Never

4. What is the reason for levels not being checked?
   - □ Lack of time
   - □ Another reason: ____________________

Thank you for participating 😊 Zuzana