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BSMMIC006

Assessment of the effectiveness of Electronic Gatekeeping as a utilization management tool at Groote Schuur Hospital

MMED – CLINICAL PATHOLOGY

UNIVERSITY OF CAPE TOWN

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i. Declaration:

Declaration:

I declare that the research reported is based on independent work performed by me. Neither the whole work nor any part of it has been, is being, or is to be submitted for another degree to any other university.

This work has not been reported or published prior to registration for the abovementioned degree.

Signed by candidate

24 July 2018

ii. Abstract:

Assessment of the effectiveness of Electronic Gatekeeping as a utilization management tool at Groote Schuur Hospital

BACKGROUND: Utilization management ensures the appropriateness of laboratory testing by reducing the performance of tests which can be reasonably avoided with no adverse effects for the patient. Electronic gatekeeping, a utilization management tool, was introduced at Groote Schuur in 2010. Criteria were based on the minimum retesting interval, healthcare location, level of experience and discipline of the requesting clinician and specific ICD-10 codes.

METHODS: A retrospective observational study assessing the effectiveness of electronic gatekeeping at Groote Schuur Hospital (Cape Town, South Africa), by comparing the test request volumes by using absolute test numbers and pre-defined ratios in the year prior to gatekeeping, to the two years following implementation. A secondary aim is to apply selected ratios to the other national academic hospitals to determine the potential for cost saving.

RESULTS: At the medical wards of Groote Schuur Hospital there was an overall decrease in number and cost of tests of 24% per inpatient day for 2011. The most dramatic difference in cost is seen for chloride (91%) followed by HbA1c (90%), FT3 (89%) and CRP (82%). The application of ratios to Groote Schuur Hospital show a decrease in 2011 in all ratios apart from PCT: FBC+WCC (0.003 vs 0.002) and Mg: Ca (0.86 vs 0.84). AST: ALT remained the same at 0.55. This suggests overall effectiveness of the eGK rules although there is ongoing panel requesting. If the GSH eGK rules were to be applied at all other national academic hospitals, it could translate into a potential cost saving of $13 411 873.96 (R103 196 838.80) per annum.

CONCLUSIONS: Electronic gatekeeping is an effective utilization management tool at Groote Schuur Hospital. It is relatively easy to implement and manage, and when combined with additional tools has the potential to result in larger reductions of unnecessary tests, cost savings and improved patient outcome.

iii. Acknowledgement and contributions:

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iv. List of tables:

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vi. Abbreviations:

ACB - Association for Clinical Biochemistry
Alb – albumin
ALP – alkaline phosphatase
ALT – alanine transaminase
AST – aspartate transaminase
Ca – calcium
CD4 – cluster designation 4
Cl – chloride
CMP – calcium, magnesium, phosphate
CPOE - Computerised Provider Order Entry systems
Creat – creatinine
CRP – C-reactive protein
Dbili - direct bilirubin
eGK – electronic gatekeeping
FBC – full blood count
fT3 - free triiodothyronine (fT3)
fT4 – free thyroxine
GGT – gamma glutamyl transferase
GSH – Groote Schuur Hospital
HbA1c – glycated haemoglobin
HIV – Human Immunodeficiency Virus
ICD-10 - International Classification of Diseases 10th Revision
ID – infectious diseases
K – potassium
LFT – liver function tests
Mg – magnesium
MRI – Minimum Retest Interval
Na – sodium
NHLS – National Health Laboratory Service
PCT – procalcitonin
Phos – phosphate
Rheum - rheumatology
Tbili - total bilirubin
TFT – thyroid function tests
TP – total protein
TSH – thyroid stimulating hormone
UEC – urea, electrolytes, creatinine
WCC – white cell count

vii. Chapter 1: Introduction and literature review

Laboratory medicine is faced with continual pressure to improve standards of healthcare whilst simultaneously removing inefficiencies and reducing cost (1). Commonly cited statistics report that 70-80% of decisions affecting diagnosis or treatment are influenced by laboratory investigations (2, 3); and that 25-30% of all requests are inappropriate (1). It is further estimated that laboratory workload increases by 10% each year without a corresponding increase in funding or staffing (4).

The healthcare expenditure must be viewed within the context of the specific healthcare system. In 2012 the UK NHS spent £2.5 billion on pathology investigations which was 4% of the total NHS expenditure of £106 billion (2, 3). The USA, with a fundamentally different healthcare system, spends approximately five times more (5) with an estimated 4-5 billion tests per annum at a cost of US$ 4 billion (6, 7). In South Africa 3.5% of the provincial budget is directed towards pathology services in the public sector. In the 2011/2012 budget, R121 billion was spent on healthcare with pathology services costing R4.2 billion (8). The Carter Report, a UK Department of Health commissioned review, stated that 20% (£500 million) can be saved by more efficient use of laboratory services. Extrapolating these figures to South Africa this equates to approximately R800 million in potential savings (1, 3, 8).

Utilisation/demand management:

Utilisation or demand management aims to ensure the appropriateness of laboratory test requesting. It not only aims to reduce the volume of requests (demand control) but contains a quality aspect which may therefore result in an increase or decrease in testing (1).

Importance of utilisation management:

The importance of utilisation management lies in the fact that although laboratory testing forms a small part of healthcare expenditure, it often results in costly downstream care and investigations, the magnitude of which is difficult to estimate but is likely to be substantial (2, 9).
Laboratory testing is influenced by patient-, doctor-, and policy or organisation-related factors (10). Utilisation management goes hand in hand with what is considered appropriate. A proposed definition is those tests that could reasonably be avoided with no significant detriment to patient care (5). The definition is challenging as there are no evidence-based standards to refer to, and what is appropriate is subject to the clinical context of the patient (11).

Inappropriate requesting is widespread. Van Walraven and Naylor's systematic review estimated 15-56% variability between centres and practices (5). The reasons for this variability include differences in clinical practice and uptake of scientific guidelines, confirmed by Smellie when assessing requesting practices in general practice in the UK (12-14). Inappropriate requesting may apply to overutilization or underutilisation and to initial and repeat requests. Overutilization/over requesting applies to tests that are requested with no indication. Underutilisation refers to tests that are indicated but not requested (7). A 15-year systematic review found an overall rate of inappropriate overutilization of 20.6% (43.9% initial and 7.4% repeat) and a mean rate of inappropriate underutilisation of 44.8% (7).

Outcomes of inappropriate laboratory tests may be obvious such as a waste of financial resources. The second and perhaps more important is the impact it has on the patient. It may have no impact, a negative impact or simply a noneconomic impact (9). An inappropriate request with no impact occurs with redundant testing, such as inadvertent repeats. There is no benefit or harm for the

patient but there is a negative financial impact (9). A negative impact occurs when the testing triggers a "Ulysses syndrome" when false positive test results lead to expensive and potentially dangerous diagnostic workups (9). Negative impacts for the patient include unnecessary discomfort, iatrogenic anaemia (13), vascular and nerve injury, introduction and spread of infection (15) and morbidity due to delayed or missed diagnosis due to underutilisation (7).

Reasons for inappropriate requesting:

Inappropriate requesting can arise from the laboratory; the requestor; the patient; or from a broader policy context (1, 2).

Laboratory: This may occur with reflex testing, poor turnaround time of results or inadequate repertoire review (1).

Requestor: There are several thousand commercially available laboratory tests with constant availability of new tests and methods (9). Requestors may be inexperienced (13) or succumb to patient and peer pressure (1). The convenience aspect such as the presence of an arterial line in situ (15) may also lead to increased testing. Many requestors are unaware of the test indications and costs, the recommended retesting intervals and may overestimate accuracy. Many report uncertainty about result interpretation (1, 2, 9) and formal training regarding appropriate utilisation is generally inadequate (13). Requestors may also practice defensively although in truth the failure to follow-up a result, or the misinterpretation thereof is a more common cause for medical malpractice litigation than faulty data gathering (1, 9, 13).

Patient: Patients may be unwilling to return for phlebotomy which results in testing to accommodate them (1, 15). Patients are the advocates of their own health and may expect blood tests to be performed following internet searches with little appreciation for the limitations of testing (2, 4, 16).

Systemic (broader policy context): Duplicate test requesting may occur with a breakdown in communication between sites resulting in requestors being unable to access previous results (1, 5).

Utilisation management interventions:

The reasons for test requesting are complex and therefore behaviour modification initiatives are unlikely to be effective if single strategies are used or if the underlying barriers to behaviour change are not targeted (10, 17).

Interventions can be divided into two categories: within-laboratory and pre-laboratory(1). Laboratory-based interventions may reduce inappropriate requests but do not have a patient focus. They do not prevent unnecessary phlebotomy, loss of work days or the expense of attending hospital (1, 18).

<u>Within-laboratory:</u>

Measures include repertoire review, vetting and within-laboratory alteration of requests, assessment of duplicate requests and retest intervals, gatekeeping and appending information to reports.

Repertoire review: The test repertoire should constantly be reviewed to meet needs and respond to new developments. It may not change the volume of testing but is reported to improve turnaround time (1).

Vetting and within-laboratory alteration of requests: High cost and low volume test numbers can be reduced. A large review of laboratory testing patterns found that low volume tests (ordered at least

10 times less frequently) are associated with a 3 times greater number of inappropriate requests (17).

Laboratories may alter test requests internally using reflex or reflective testing protocols. This concept was demonstrated to improve the appropriateness of test requesting in 1988 by Finn et al (1). Diagnostic investigations beginning with cheap, sensitive, non-specific tests followed by predefined specific tests without input from the requestor is known as reflex testing. It can be complemented by reflective testing where laboratory professionals add tests based on the result and clinical information (19).

Some authors feel it is not justifiable to cancel a requested test without consultation and the way to circumvent this is to require that certain test requests be justified before they are fulfilled (19). A straightforward method is telephonic or email contact with the requestor. This method is not feasible as it is labour intensive and disruptive to both the laboratory and requestor (19).

Assessment of duplicate requests and retest intervals: Minimum retest intervals (MRIs) are established using published guidelines, analyte half-life and reference change values. These intervals can then be used to identify duplicate requests to which automatic rejection or individual vetting can then be applied (1). MRIs can be applied universally or to selected requestors and locations (1). Tyrrell et al achieved overall reduction in total requesting activity of 22.7% with MRIs (20). With Computerised Provider Order Entry systems(CPOE), the request may be prevented prior to phlebotomy (1) which is the ideal scenario. The association for clinical biochemistry (ACB) has a national minimum retesting interval project which provides a set of consensus/evidence-based recommendations (4).

Selective limitations on test requesting: Some laboratories may establish criteria by which certain test requests will only be performed with pathologist approval (9). Others limit requests based on specialty or staffing grade (1). In Hutton's study assessing CRP requesting patterns, the implementation of consultant-only requesting resulted in an overall reduction of 85% (21). This is however difficult to enforce and monitor (1).

A seldom used strategy is that of rationing. Dixon et al noted that only 5% of laboratory results influenced patient management. They performed a study where laboratory test requesting was limited patients to 8 tests per day. The number of tests ordered decreased by two-thirds and the percentage of tests that influenced management went from 5 to 23% (22). This strategy threatens clinician autonomy however (13) and there must be measures in place to circumvent the limit (22).

Gating test activity (gatekeeping): Setting criteria whereby tests will not be performed if a request reaches the laboratory is an attractive way of limiting overtly inappropriate requests. The most obvious examples are for frequent repetition of monitoring tests or duplication of investigations. It may be argued that duplication of a test or repetition within a short time is not necessarily inappropriate (5) and there must be a way in which to deviate from the policy (10). It may also be argued that gatekeeping must be restricted to inappropriate utilisation as it is counterproductive to harass requestors by imposing excessive obstacles to requesting (23).

Two local retrospective studies assessed electronic gatekeeping on high volume chemistry tests. Smit et al noted that 6.7% of tests were rejected of which 14.7% were restored. They concluded that patient care was unaffected in 80% with a cost saving of £25,387 (24). Pema et al reported savings of $84,380 which was not felt to be as dramatic as expected (25).

A study assessing the requesting of ANCA showed that a gating policy which refused analysis not supported by clinical data made clinicians more selective (26). A study at the Feinberg School of Medicine used a combination of education and gatekeeping. Tests costing more than $500 required approval by the laboratory medical director. They evaluated a paraneoplastic panel costing $1757.50 with a turnaround time of 14-21 days. 9 of the 15 requests were cancelled, in discussion with the requestor, saving $15817.50 (27).

Reducing the availability of on-site testing: In this instance, testing is available at certain times only, by offering a selected testing package outside office hours and during holiday periods (19).

Pre-laboratory:

Pre-laboratory interventions include education, request form design, the use of profiles and test combinations, financial incentives and penalties, and the use of information technology to support decisions.

Education: In the review by Solomon et al, educational interventions were present in most of the successful studies identified (10). Education may be verbal, written or electronic (1); it can be active or passive (9); pulled (in response to a request) or pushed (unsolicited) (9).

Pulled education is provided by pathologists and clinical scientists who are available to respond to clinical queries. This approach would be more efficient when provided in an easily accessible format such as a website. In this way, test requesting can be linked to online test directories when using CPOE (9).

Pushed education can be provided at the time of request using CPOE, or through laboratory reports. An intensive approach is the provision of written materials as well as face-to-face interactions between requestor and the laboratory in a manner similar to pharmaceutical or medical device sales (9).

Solomon et al noted that educational approaches were most successful when interventions targeted multiple behavioural factors (1), confirmed by Greco and Eisenberg's 1993 study (10). Active education has also been found to be more effective, yet passive methods remain the most widespread (9).

An important form of education is the use of feedback and reminders. Verstappen et al used education with personalised graphical feedback including a comparison of each physician's own data with those of colleagues resulting in a 16% reduction of inappropriate tests (2). Thomas et al performed a study using quarterly feedback of requesting rates and reminder messages. The feedback included a booklet containing graphical presentations of individual practice ordering for targeted tests. Educational reminders were developed in conjunction with the physicians and were included with test results. They noted a 11% reduction in requests for practices receiving enhanced feedback or reminder messages and a combined reduction of 22% in total number of targeted tests ordered (2). Elnenaei et al's study provided written feedback and evidence-based highlights to clinicians identified as having substantially higher requests. The outcome was an overall reduction of 50% in the number of tests (28). Baker et al used guidelines followed by feedback for thyroid function tests, rheumatoid factor and urine cultures. They noted no effect, and this may be a function of how often and the way it is provided. Individualised feedback has been shown to be more effective than general feedback, in particular when it is regular, repeated and timely (2). Senior colleagues may also review the testing practices of junior colleagues in order to provide them with feedback (22).

Guideline education: Guidelines on test requesting are often aimed at the laboratory instead of requestors and when included in general guidelines the information may be hidden amongst management and treatment instructions (1). A study by Driskell et al assessed the appropriateness of HbA1c requests. They found that 49% of requests conformed to guidance despite guidelines on testing frequency being available from the ADA, NICE and Canadian diabetes association. This led to the conclusion that the publication of guidance had no significant impact on under/over requesting rates (3) and it has been noted elsewhere that guidelines alone are the least productive way of effecting change (5). Tomlin et al used a combination of guidelines, education and feedback for ESR requests and noted a 60% reduction in the number of requests (2). Guidelines need to be specific in order to be of positive use (10).

Face-to-face sessions: in an approach referred to as academic detailing, written materials are provided as well as interactions with clinicians in a manner similar to pharmaceutical or medical device sales. This is intensive and costly and the expense may exceed potential savings (9). Barrichi et al designed pathology-specific algorithms for 7 common clinical scenarios and educated physicians about their use over eight training sessions. This intervention resulted in a 5% reduction in volume of tests requested. Larsson et al educated primary care physicians using a 2-day lecture series. Each participant received a folder containing information relating to the guidelines for future reference. They noted significant changes for 9/14 tests (2).

Information technology and decision support: The ideal solution would be to provide information about best practice in real time using software systems which allow prompting at the point of request through the use of simple logic rules of web browser technology (5). A 2001 study by Van Wijk et al compared a guideline-based order form with a restricted guideline-based electronic order form. The group using the guideline-based form requested 20% fewer tests on average (2, 10).

Test-report-based education: A concise footnote may be added to clarify the indications of a test, and the recommended follow-up testing and repeat interval. Salinas et al performed a study in which all requests for 1,25OHD were replaced by 25OHD and a comment as to the clinical utility was added. They noted that the requests for 25OHD increased with a corresponding decrease in 1,25OHD requests (29). Education can also be provided at the time of request when computer order entry is used (9) although it has been reported that these methods only affect behaviour to a moderate extent (1).

Request form design: The interface between the clinician and the laboratory is the request form, whether electronic or paper-based (13). The form or electronic order menu can be redesigned to reorganise tests, remove a test or replace with a better alternative. Cost information can also be displayed (9).

Removal of a test from the request form is usually based on consensus expert opinion as there is usually no high-level evidence (10). In the review by van Walraven et al, urea requests decreased by 57%, ESR requests decreased 58% and TSH requests decreased by 12% when removed from request form (30). Shalev et al reported a 27% reduction in deleted tests after removing 27 tests and adding 2 (2). Zaat et al changed the request form to list 15 tests. They noted a 18% reduction in number of tests requested monthly (2). Bailey noted a 60-80% reduction when removing certain analytes from profiles (10). Yeh et al states that removal of the test from “quick-pick” order screens resulted in an immediate decrease of 50% (13). Seppanen et al removed ESR and AST from their computerised laboratory test order form resulting in a 90% decrease in their use (31).

Emerson et al changed the listing order leading to significant changes in utilization. Wong et al grouped thyroid function studies by clinical status which resulted in a 62% reduction in inappropriate tests(13, 22).

Display of cost information: Horn et al displayed real-time cost information at the time of ordering. The change was dependent on the specifics of the test with reductions in higher cost tests in only 1 of 6 tests (2). The success of this method is limited by the fact that many tests are requested because of clinically absolute reasons which are not affected by cost (1).

Profiles and test combinations: The list of tests on a request form may be numerous and the use of test profiles can simplify the requesting process. These profiles are usually organ-based (1) with the advantage that investigation protocols are tailored to a diagnosis (5). There is generally considerable variation in profiles and not all tests are specific to the organ system in question. The National Pathology Benchmarking Service (UK) demonstrated 12 different profiles for 'liver function test' for example (1).

The problem with organ-based profiles is that patients may present with nonspecific symptoms and investigation may span different organ systems. Additionally profile-based testing results in inappropriate tests when used for monitoring (1). Admission profiles may be used to ensure that important tests are not omitted. They may also reduce inappropriate requests being added (1).

Financial incentives and penalties: The United States model uses a fixed tariff to physicians based on an episode of care (1). Purely financial mechanisms could be detrimental to overall health-care provision as they potentially undermine quality, offering no rational system to ensure appropriate changes in requesting (10). Modest financial rewards at the provider level are not consistently effective and larger rewards run the risk for conflicts of interest for patient well-being (13).

Spitzer reported that 50% of all laboratory requests are made without considering cost (22) however in van Walraven's study, when a medical plan stopped funding T4 testing, requests decreased by 96% (30).

Information technology and decision support: Electronic medical record systems allow for viewing of laboratory results and some allow for online test requesting. Information technology systems may influence requesting by making historic results easier to view at the time of request, and so reduce repeat orders. CPOE may be linked to feedback and decision support systems (9). Pop-up reminders of redundant or outmoded tests may be used to educate ordering physicians as long as they are not too intrusive (13). Young et al noted that decision support systems require significant technical support and medical supervision to keep protocols up to date (22).

Conclusion:

Inappropriate testing is widespread with large variation noted between different institutions and practices. Utilisation management is a way of decreasing the number of inappropriate requests, whether this results in increased or decreased testing, and improving patient outcomes.

There are several different utilisation management strategies however the most effective approaches are those that target multiple behavioural factors.

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viii. Chapter 2: Publication-ready manuscript

Laboratory medicine is faced with continual pressure to improve standards of healthcare whilst simultaneously removing inefficiencies and reducing costs (1). Laboratory investigations influence 70-80% of healthcare decisions (2, 3) with 25-30% of all requests being inappropriate (1). In the 2011/2012 South African national budget, R121 billion was spent on healthcare with 3.5% of the provincial budget directed towards pathology services in the public sector at a cost of R4.2 billion (4). The Carter Report, a UK Department of Health commissioned review stated that 20% (£500 million) can be saved by more efficient use of laboratory services in the National Health Service (NHS). Extrapolating these figures to South Africa, this equates to approximately R800 million in potential savings (1, 3, 4).

Utilization or demand management is a means by which the appropriateness of laboratory test requesting is ensured (1). A proposed definition is those tests that could reasonably be avoided with no significant detriment to patient care (5).

Inappropriate requesting is widespread with an estimated 15-56% variability between practitioners and centres (5). Potential explanations offered are differences in clinical practice and either the lack of established scientific guidelines or differences in the application thereof (6-8).

Inappropriate requesting may lead to overutilization or underutilization and may apply to initial and repeat requests (9). It can arise from the laboratory (reflex testing, poor turnaround time of results, inadequate repertoire review) (1); from the requestor (inexperience (10), inability to select appropriately from the large number of commercially available tests (8), patient or peer pressure (1), lack of awareness of indications, cost, recommended retesting intervals (11), convenience testing in a busy practice, and the practice of defensive medicine (1, 8)); and from the patient who may be unwilling to return for phlebotomy (1, 10). Patients are increasingly becoming the advocates of their own health and may expect blood tests to be performed following internet searches with little appreciation for the limitations of testing (11-13). A systemic reason may be a breakdown in communication between sites resulting in duplicate testing (1, 5).

The obvious outcome of an inappropriate laboratory request is a waste of financial resources. Secondly and perhaps more importantly is the impact it may have on the patient. Negative impacts as a result of overutilization occur when testing triggers potentially expensive and dangerous diagnostic workups and therapies following false positive results (14). Additional negative impacts include unnecessary discomfort, iatrogenic anaemia (7), vascular and nerve injury and introduction and spread of infection (10). A negative impact associated with underutilization is increased morbidity due to delayed or missed diagnoses (9).

Interventions can be divided into two categories: pre-laboratory and within-laboratory (1). Pre-laboratory interventions include education, request form design including the display of cost per test, unbundling of tests, discouraging the use of profiles, and the use of information technology to support decisions (15). Laboratory-based interventions may reduce inappropriate requests but lack a patient focus (1, 16). These include repertoire review, vetting, within-laboratory alteration of requests, preventing duplicate requests, minimum retest intervals (MRIs), gatekeeping and appending information to reports. Tyrrell et al achieved overall reduction in total requesting activity of 22.7% with MRIs (17). Additionally, laboratories may establish criteria by which certain test requests will only be performed with pathologist approval (14), or limit requests based on specialty (1). In Hutton's study assessing C-reactive protein (CRP) requesting patterns, the implementation of

consultant-only requesting resulted in an overall reduction of 85% (18). This is however difficult to enforce and monitor as clinicians may resort to using the names of colleagues for restricted tests (1).

Gatekeeping is a utilization management tool whereby clinical and logical criteria are determined for the appropriate use of specific tests. If any parameter falls outside of the criteria the test is rejected. This is most obviously applied to repetition or duplication of investigations (5). Two local retrospective studies assessed electronic gatekeeping on high volume chemistry tests. Smit et al noted that 6.7% of tests were rejected of which 14.7% were subsequently restored. They concluded that patient care was unaffected in 80% of cases with a cost saving of £25,387 over the 6-month study period (19). Pema et al reported savings of $84,380 over a 22 month period with the most notable savings in glycated haemoglobin (HbA1c), thyroid stimulating hormone (TSH) and urea (20).

At Groote Schuur Hospital (GSH) test utilization practice changes were introduced in 2009, when test request protocols for various targeted analytes (CRP, free thyroxine (fT4) and HbA1c) were developed in consultation with a clinical team of senior clinicians. At this time the expectation was that there would be voluntary compliance after education. The test costs were also added to the request form at the time, as per the request of the National Department of Health.
In January 2010, following poor compliance, manual gatekeeping was enforced by a hospital appointed laboratory gatekeeper. This process entailed manual checking of request forms which was labour-intensive, delayed test turn-around time and provided limited scope.

In September 2010, electronic gatekeeping was introduced for a larger scope of analytes. High volume and high cost tests (urea, creatinine, liver functions, CRP, HbA1c, thyroid function tests, full blood count, CD4 and HIV viral load) were targeted. A system of authorisation numbers was instituted to prevent rejection or to allow the restoration of tests. These numbers were managed by the medical superintendent and implemented by the laboratory. Gatekeeping criteria were based on the minimum retesting interval, the level of healthcare (location), the level of experience and discipline of the requesting clinician and specific ICD-10 codes (*Table 1*). The implementation of electronic gatekeeping at Groote Schuur formed part of a pilot project in the Western Cape.

The aim of this study was to assess the effectiveness of electronic gatekeeping at Groote Schuur Hospital by comparing the test request volumes and cost per inpatient day in the year prior to the implementation of gatekeeping, to the two years following the implementation of electronic gatekeeping. In addition, the test request volumes of tests subject to gatekeeping was compared to tests without gatekeeping.

A secondary aim was to determine the potential cost saving if the same criteria were applied across the other national academic hospitals by means of selected ratios.

This is the first study of this kind to be performed at Groote Schuur Hospital and the first study assessing potential national cost savings in South Africa.

Group	Test	MRI Restriction (Minimum Retest Interval)	Other restriction	Unrestricted	Use in profiles
Metabolic tests	Sodium			No eGK	"UEC" profile
	Potassium			No eGK	"UEC" profile
	Chloride		Specialist only		Not in "UEC" profile
	Urea	Inpatient: 24 hours; Outpatient: 2 weeks			"UEC" profile
	Creatinine	Inpatient: 24 hours; Outpatient: 2 weeks			"UEC" profile
Liver function tests:	Total protein	1 month			Not in "LFT" profile
	Albumin			No eGK	Not in "LFT" profile
	Total bilirubin	Inpatient: 2 days; Outpatient: 1 week			
	Direct bilirubin	1 week			Not in "LFT" profile
	ALT	Inpatient: 2 days; Outpatient: 1 week			
	AST	Inpatient: 2 days; Outpatient: 1 week			Not in "LFT" profile
	ALP	Inpatient: 2 days; Outpatient: 1 week			
	GGT	Inpatient: 2 days; Outpatient: 1wk			Not in "LFT" profile
Infection markers:	CRP	ID / Rheum wards only: Repeat within I week Rest of wards: No repeat unless previous result abnormal			
	PCT			No eGK	
	FBC	Inpatient: 24 hours; Outpatient: 4 weeks			
	WCC			No eGK	
Glycaemic control:	HbA1c	Obstetric/Diabetic: 1 month Other wards: 6 months	Other wards: No first-time requests		
	Glucose			No eGK	
Thyroid function	TSH	3months			
	Free T4	No MRI. FT4 added when TSH abnormal			Not in "TFT" profile
	Free T3	No MRI.	Selected specialists only		Not in "TFT" profile
	Ca	No MRI.			"CMP" profile
	Mg		Selected specialists only		"CMP" profile
	Phos	No MRI.			"CMP" profile

Table 1. Electronic gatekeeping criteria implemented at Groote Schuur Hospital in 2010 (see Abbreviations in section iv)

Methods:

STUDY DESIGN: The study is a retrospective observational study.

DATA COLLECTION: The subjects are Groote Schuur Hospital (Cape Town, Western Cape) and the other national South African academic hospitals, namely Charlotte Maxeke Hospital (Johannesburg, Gauteng), Chris Hani Baragwanath Hospital (Johannesburg, Gauteng), Dr George Mukhari Hospital (Pretoria, Gauteng), Inkosi Albert Luthuli Central Hospital (Durban, Kwazulu-Natal), Mthatha Hospital (Mthatha, Eastern Cape), Tshwane Academic Hospital (Pretoria, Gauteng), Tygerberg Hospital (Cape Town, Western Cape) and Universitas Hospital (Bloemfontein, Free State).

Data were extracted from the National Health Laboratory Services (NHLS) Laboratory Information System (LIS). The year 2008 was selected as the "pre-electronic gatekeeping" period. The years 2011 and 2012 were selected as the "post-electronic gatekeeping" period. This allows an assessment to be made as to whether the change was sustained. Data was extracted for Groote Schuur Hospital (2008, 2011 and 2012) as well as the other tertiary academic hospitals in South Africa (2012). Groote Schuur Hospital provided data on the number of patient days for the medical wards.

Data were collected for: C-reactive protein (CRP), glycated haemoglobin (HbA1c), procalcitonin (PCT), full blood count (FBC), white cell count (WCC), creatinine (Creat), urea, sodium (Na), potassium (K), chloride (Cl), calcium (Ca), magnesium (Mg), phosphate (Phos), thyroid stimulating hormone (TSH), free thyroxine (fT4), free triiodothyronine (fT3), liver function tests (LFT) comprising total protein (TP), albumin (Alb), total bilirubin (Tbili), direct bilirubin (Dbili), alanine transaminase (ALT) and aspartate transaminase (AST), and glucose.

Outpatient clinics and surgical wards were excluded and data were limited to chemical pathology and occasional haematology tests.

DATA ANALYSIS: Data analysis consisted of two components.

Firstly, the number of tests processed from all adult medical inpatient wards at Groote Schuur Hospital were compared before and after the implementation of electronic gatekeeping. Adult medical wards were selected as a representative sample. The number of tests processed is expressed per inpatient day (a measure of hospital occupancy for the number of beds available), using the equation: inpatient days + (1/2 of Day patients))/Bed days / 975 (number of beds). This standardises for potential changes in patient numbers. This number was calculated and supplied by Groote Schuur Hospital management. The cost of testing was determined using the NHLS tariffs in 2012/2013.

Secondly, selected test ratios were used to assess the overall impact of electronic gatekeeping on test request patterns at Groote Schuur Hospital, pre- and post-electronic gatekeeping for the whole hospital (*Table 2*). The ratios were also applied to the other academic hospitals in South Africa to allow the formulation of a hypothesis as to the potential cost-saving if the same gatekeeping rules were to be applied nationally. The institution names are not listed for the remainder of the manuscript and are presented in a non-alphabetic but consistent order. To compare cost of testing, Groote Schuur was taken as the comparator and the ratios for tests performed at each of the academic hospitals (GSH 2012) were provided as multiples of the corresponding GSH ratio in 2012.

The potential savings were calculated by subtracting the amount calculated using the ratio from the total number of tests performed per hospital in 2012. The savings were presented in South African Rand (ZAR) and US Dollar (USD), converted using an average of the ZAR-USD exchange rates from 2008, 2011 and 2012 (1ZAR = 0,129964 USD) (21).

Ratio	Rationale
CRP: [FBC+WCC]	FBC / WCC is requested routinely. If the ratio is ≥ 1 then this suggests inappropriate testing. FBC and WCC analysed together as WCC is often not requested alone.
PCT: [FBC+WCC]	This ratio assesses whether the PCT: [FBC / WCC] testing increased due to CRP gatekeeping.
fT4: TSH	With the implementation of gatekeeping any request for thyroid functions will result in a TSH being performed (with fT4 reflex testing when the result is abnormal). A ratio < 1 implies a decrease in fT4 testing which would suggest decrease in "Thyroid Profile" testing.
fT3: TSH	Free T3 is only allowed by specific requestors. The ratio indicates the effectiveness of gatekeeping. A ratio < 1 suggests decreased "Thyroid Profile" testing.
fT3: fT4	Free T3 should be performed when the patient is on T3 therapy or when the TSH and fT4 results are not well explained. This ratio should be < 1 and indicates whether testing is being performed appropriately.
AST: ALT	This ratio indicates whether fewer full LFT panels were performed. When "LFT" is requested then Alb, Tbili, ALT, and ALP are performed. AST is performed only when specifically selected. Since ALT is more liver-specific, a decreased ratio implies a decrease in inappropriate requesting.
TP: ALT	Frequent testing of total protein testing is inappropriate since a clinically significant change cannot be interpreted without albumin testing. The ratio will also assess the decrease in the number of full LFT panels performed after implementation of gatekeeping.
urea: creatinine	Before gatekeeping the request for urea + creatinine would have resulted in testing of both analytes. After gatekeeping, such a request would result in only creatinine being performed instead.
chloride: sodium	Chloride is subjected to electronic gatekeeping. The ratio will reflect whether eGK resulted in a decrease in UEC panel testing. Sodium requesting is not restricted.
HbA1c: Creatinine	Urea, electrolytes and creatinine are performed routinely, mainly in diabetic patients. This ratio assesses whether HbA1c is also performed in a routine manner.
Mg: Ca	Magnesium testing only performed on consultant request. This ratio assesses whether gatekeeping affected the number of calcium, magnesium and phosphate (CMP) panel requests.

Table 2. Ratios for comparison of GSH (Pre and Post-eGK) and GSH with other national hospitals (see Subject Selection in Methods)

ETHICS: The study was approved by the Health Research ethics committee of the Faculty of Health Sciences University of Cape Town. The data is retrospective and anonymous with no individual patient results or identifiers. Informed consent was not required.

Results:

Change in request patterns in GSH:

The number of tests performed per inpatient day in the medical wards was compared for the assessment periods of 2008, pre-electronic gatekeeping (eGK) and 2011, post-eGK. *Table 3* demonstrates the absolute changes in number and cost per test per inpatient day.

Analyte	2008		2011		Change	
	Tests per inpatient day	Cost per inpatient day	Tests per inpatient day	Cost per inpatient day	Tests per inpatient day	Cost per inpatient day
Sodium	0.21	R5.55	0.25	R6.57	0.04	R1.02
Potassium	0.21	R5.55	0.26	R6.91	0.05	R1.36
Chloride	0.05	R0.91	0.004	R0.08	-0.04	R-0.83
Urea	0.21	R5.56	0.24	R6.21	0.02	R0.65
Creatinine	0.22	R5.72	0.26	R6.90	0.04	R1.18
Total protein	0.09	R2.07	0.02	R0.47	-0.07	R-1.60
Albumin	0.12	R4.05	0.06	R2.01	-0.06	R-2.04
Total bilirubin	0.12	R3.59	0.06	R1.92	-0.05	R-1.67
Direct bilirubin	0.10	R2.36	0.03	R0.79	-0.07	R-1.56
ALT	0.13	R4.94	0.08	R3.09	-0.05	R-1.85
AST	0.11	R4.46	0.06	R2.36	-0.05	R-2.10
ALP	0.12	R4.62	0.06	R2.38	-0.06	R-2.24
GGT	0.11	R4.52	0.06	R2.27	-0.06	R-2.26
CRP	0.04	R3.17	0.01	R0.56	-0.03	R-2.61
PCT	0.01	R1.71	0.002	R0.70	-0.003	R-1.01
FBC	0.19	R9.45	0.18	R9.21	-0.005	R-0.24
WCC	0.01	R0.18	0.01	R0.18	-0.0002	R-0.003
HbA1c	0.003	R0.26	0.0004	R0.03	-0.003	R-0.23
Glucose	0.012	R0.33	0.004	R0.22	-0.01	R-0.22
TSH	0.01	R1.88	0.01	R1.19	-0.005	R-0.69
Free T4	0.01	R1.15	0.003	R0.35	-0.01	R-0.80
Free T3	0.002	R0.29	0.0002	R0.03	-0.002	R-0.26
Ca	0.05	R1.26	0.05	R1.26	0.0002	R0.01
Mg	0.04	R1.14	0.05	R1.19	0.002	R0.05
Phos	0.04	R1.13	0.04	R1.13	-0.0002	R-0.004

Table 3. Absolute changes in number and costs of tests performed per inpatient day. (-) indicates a decrease in cost. The cost is calculated using NHLS tariffs from 2012/2013.

Decreases in testing were seen for Cl, TP, CRP, HbA1c, fT4, fT3, Alb, Tbili and Dbili, ALT, AST, ALP, GGT, FBC, TSH, Gluc and PCT.

Testing increased for urea, Creat, Na and K while remaining unchanged for WCC, Ca, Mg and Phos.

Testing patterns between 2011 and 2012 are similar when compared to 2008 (see supplementary – *Table 1*).

Cost savings achieved at GSH following EGK:

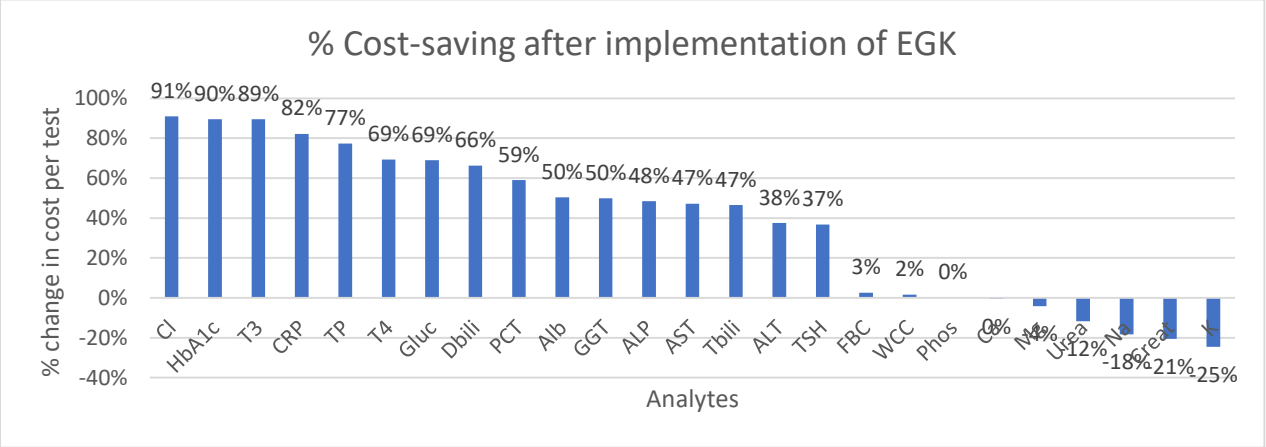

Figure 1. % Cost-saving after eGK implementation at Groote Schuur Hospital (2011). Negative values refer to cost increases.

Figure 1 represents the % cost-saving per inpatient day in 2011 when compared to 2008. There was an overall decrease in cost of 24% per inpatient day.

The most dramatic difference was seen for chloride (91% - R0.91 to R0.08 per test per inpatient day) followed by HbA1c (90% - R0.26 to R0.03), FT3 (89% - R0.29 to R0.03) and CRP (82% - R3.17 to R0.56). The difference in cost of R2.61 for CRP is the biggest monetary saving.

White cell count showed the smallest cost-saving (2%). There was no cost-saving for calcium and phosphate. Magnesium cost increased by 4%, urea by 12% and creatinine by 21%, despite gatekeeping.

Sodium and potassium were not subject to electronic gatekeeping. The cost per test increased by 18% and 25% respectively.

Tests with the highest cost per inpatient day are: FBC (R9.45), Creatinine (R5.72) and Urea (R5.56). Following the implementation of gatekeeping the cost for FBC decreased to R9.21. Creatinine increased to R6.90 (21%) and urea to R6.21 (12%).

Test ratio changes within GSH after EGK (Figure 2):

The following ratios demonstrated a decrease (2011 vs 2008): CRP: FBC+WCC (0.07 vs 0.15), fT4: TSH (0.43 vs 0.60), fT3: TSH (0.04 vs 0.14), urea: creatinine (0.63 vs 0.88), HBA1c: creatinine (0.04 vs 0.06), Cl: Na (0.11 vs 0.32) and TP: ALT (0.21 vs 0.30).

In contrast, PCT: FBC+WCC demonstrated an increase (0.003 vs 0.002) as did Mg: Ca (0.86 vs 0.84). AST: ALT remained the same (0.55).

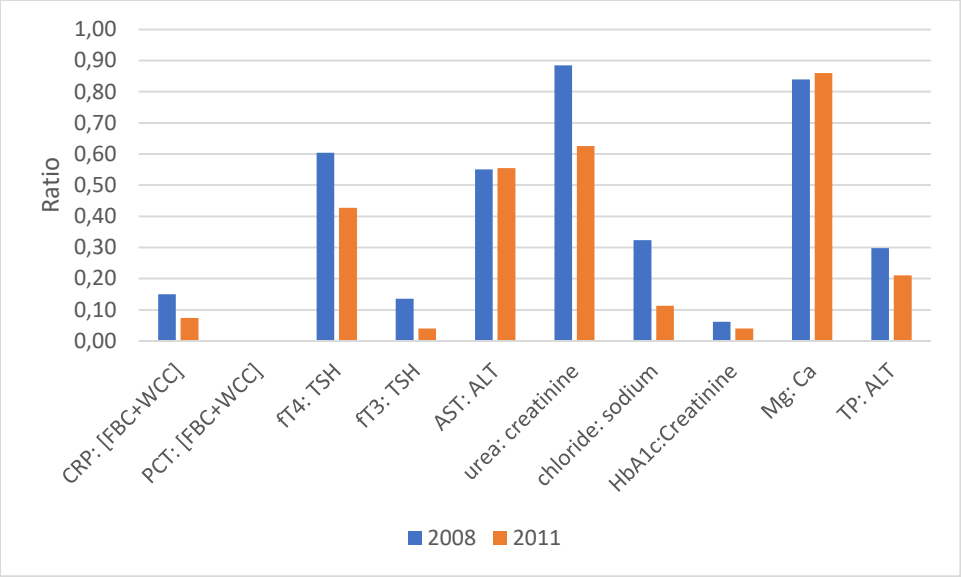

Figure 2. The ratios of analytes tested at Groote Schuur Hospital 2008 vs 2011.

Test ratio comparison between GSH and other academic hospitals in South Africa:

To compare the cost of testing, Groote Schuur was taken as the comparator with an assigned value of 1.0 and the testing pattern for the academic hospitals are provided as multiples of the GSH ratio (*Table 4* and supplement *Table 3*). A ratio of 1 would therefore suggest that testing patterns are the same as those at GSH.

Table 4 (*Table 2 supplement*) demonstrates that the majority of hospitals had ratios that were higher than those at GSH.

Hospital 10 performed 6.50 times more CRP testing than GSH. Hospital 9 and 8 performed 6.1 and 5.6 times more respectively. The GSH gatekeeping rules at hospital 10 would result in an annual cost saving of $317 313.90 (R244 1552) just for CRP. When implemented at all academic hospitals the national annual savings would approach $2 870 347 (R22 08 5707).

Hospital 10 also performed significantly more PCT tests (93.4), followed by hospital 9 (43.4) and 6 (32.8). National annual savings for this test would be approximately $3 224 952 (R24 814 195).

Chloride testing was performed 8.8 times more by hospitals 2, 3, 6 and 8. By applying the gatekeeping criteria implemented at GSH the potential national cost saving would be $1 955 233 (R15 044 418)**.**

Urea testing was performed in a similar way across all hospitals. Hospitals 6 and 10 (1.6 times more) and hospital 2 (1.5 time more). Potential cost savings amount to $983 507.70 (R7 567 539)**.**

AST testing was performed less by Hospitals 2 and 5. The remainder performed similarly to GSH. The national annual cost saving would amount to $382 118.30 (R2 940 186).

Total protein testing was performed less by Hospitals 5 and 9. Hospital 6 performed 4.5 times more than GSH. Hospitals 2 and 3 performed 4.1 and 3.1 times more respectively. National annual savings of $624 880.10 (R4 808 102) can be expected.

HbA1c was performed 8.3 times more than GSH. Hospital 8 performed 4.2 times more and hospital 10 2.4 times more. Hospital 2 performed less HbA1c tests than GSH. Total national savings amount to $961 627.50 (R7 399 184).

Free T4 testing was performed 2.4 times more by hospital 6, 2.2 times more than GSH by hospital 4 and 2.1 times more than GSH by hospitals 3 and 10. Total national savings of $1 206 955 (R9 286 843) could be expected for this test. Free T3 was performed by Hospitals 4, 6 and 3 more than 24.6, 19.3 and 15.3 times that of GSH. Total national saving of $1 106 740 (R8 515 743) can be expected with the GSH eGK rules.

When comparing the FT3: FT4 ratio, hospitals 4, 6 and 3 performed 11.6, 9.3 and 8.7 times more than GSH. Hospitals 7 and 10 performed less testing compared to GSH.

The Mg: Ca ratios were similar to the GSH ratio. Hospitals 5 and had ratios of 1.0 while the remainder had ratios of 1.1.

The total cost saving potential with GSH eGK rules would possibly exceed $13 411 873.96 (R103 196 838.80) per annum on a national scale.

	Ratio	Absolute number of tests	Cost USD	Cost ZAR	Cost-saving USD	Cost-saving ZAR
CRP: [FBC+WCC]			**10.24**	**78.81**	**2 870 347**	**22 085 707**
Groote Schuur	0.08 (1.0)	14 542	148 945.90	1 146 055		
Hospital 10	6.5	36 613	375 007.30	2 885 471	317 313.90	2 441 552
Hospital 9	6.1	48 542	497 189.60	3 825 595	420 698.90	3 237 042
Hospital 8	5.6	81 402	833 757	6 415 292	684 871.80	5 269 704
PCT: [FBC+WCC]			**43.72**	**336.41**	**3 224 952**	**24 814 195**
Groote Schuur	0.004 (1.0)	790	34 539.70	265 763.90		
Hospital 10	93.4	25 919	1 133 210	8 719 411	1 121 072	8 626 019
Hospital 9	43.4	15 734	687 909.20	5 293 075	672 067.80	5 171 184
Hospital 6	32.8	15 080	659 315.50	5 073 063	639 219.80	4 918 438
Cl: Na			**2.44**	**18.75**	**1 955 233**	**15 044 418**
Groote Schuur	0.12 (1.0)	17 339	42 252.10	325 106.30		
Hospital 2	8.8	75 360	183 639.10	1 413 000	162 673.30	1 251 680
Hospital 3	8.8	65 884	160 547.80	1 235 325	142 213.50	1 094 253
Hospital 6	8.8	104 153	253 802.60	1 952 869	224 918.50	1 730 622
Hospital 8	8.8	169 130	412 140.20	3 171 188	365 101.50	2 809 251
Urea: Creat			**3.41**	**26.27**	**983 507.70**	**7 567 539**
GSH	0.58 (1.0)	138 514	472 908.20	3 638 763		

Hospital 6	1.6	104 307	356 120.20	2 740 145	139 363.20	1 072 321
Hospital 10	1.6	82 490	281 633.60	2 167 012	108 631.80	835 861
Hospital 2	1.5	75 766	258 676.80	1 990 373	84 812	652 580.80
AST: ALT			**5.11**	**39.34**	**382 118.30**	**2 940 186**
GSH	0.59 (1.0)	49 289	252 004	1 939 029		
Hospital 2	0.3	12 549	64 160.30	493 677.70		
Hospital 5	0.7	18 459	94 376.90	726 177.10		
Hospital 6	1.8	65 873	336 794.40	2 591 444	146 417.80	1 126 603
Hospital 10	1.7	34 977	178 829.80	1 375 995	74 371.40	572 246.20
TP: ALT			**2.93**	**22.58**	**624 880.10**	**4 808 102**
GSH	0.24 (1.0)	19 714	57 852.45	445 142.10		
Hospital 6	4.5	65 556	192 379.80	1 480 254	149 770.30	1 152 398
Hospital 2	4.1	53 733	157 684.20	1 213 291	119 239.50	917 481
Hospital 3	3.1	33 133	97 231.70	748 143.10	65 394.65	503 175.20
HbA1c: Creat			**9.61**	**73.96**	**961 627.50**	**7 399 184**
GSH	0.04 (0.1)	8 851.61	85 077	654 620		
Hospital 6	8.3	41 992	403 632.90	3 105 728	97 621.20	2 731 733
Hospital 8	4.2	37 514	360 589.70	2 774 535	58 363.60	2 108 734
Hospital 10	2.4	8 225	79 059.80	608 321	11 588.20	349 974.10
T4: TSH			**16.60**	**127.75**	**1 206 955**	**9 286 843**

GSH	0.38 (1.0)	9 597	159 338	1 226 017		
Hospital 6	2.4	70 982	1 178 507	9 067 951	676 086.20	5 202 104
Hospital 4	2.2	11 008	182 764.70	1 406 272	99 829	768 128.50
Hospital 3	2.1	3 059	50 788.27	390 787.30	26 371.65	202 915.10
Hospital 10	2.1	16 760	278 264.60	2 141 090	146 586.70	1 127 903
T3: TSH			**16.60**	**127.75**	**1 106 740**	**8 515 743**
GSH	0.03 (1.0)	769	12 767.63	98 239.75		
Hospital 4	24.6	10 264	170 412.20	1 311 226	163 471.10	1 257 818
Hospital 6	19.3	53 014	880 186.20	6 772 539	834 643.50	6 422 113
Hospital 3	15.3	2 131	35 380.78	272 235.30	33 072.80	254 476.50
T3: T4			**16.60**	**127.75**		
GSH	0.08 (1.0)	769				
Hospital 4	11.6	10 264				
Hospital 6	9.3	53 014				
Hospital 3	8.7	2 131				
Mg: Ca			**3.41**	**26.27**	**95 513.44**	**734 922.30**
GSH	0.91 (1.0)	30 913	105 541.80	812 084.50		
Hospital 2	1.1	39 983	136 508.10	1 050 353	11 895.10	91 526
Hospital 3	1.1	10 901	37 217.70	286 369.30	3 549.60	27 312.30
Hospital 4	1.1	9 324	31 833.60	244 941.50	2 073.20	15 952

Hospital 5	1.0	40 593	138 590.80	1 066 378	3 381.90	26 021.50
Hospital 6	1.1	49 505	169 017.70	1 300 496	18 881.70	145 284
Hospital 7	1.1	70 340	240 151.60	1 847 832	18 816.20	144 780.30
Hospital 8	1.1	86 313	294 685.90	2 267 443	21 046.30	161 939.80
Hospital 9	1.0	38 658	131 984.40	38 658		
Hospital 10	1.1	38 745	132 281.40	1 017 831	15 869.40	122 106.30
Total					13 411 873.96	103 196 838.80

Table 4. Cost saving implications - Selected ratios of Groote Schuur Hospital and other national academic hospitals. Hospitals 2 – 10 are compared to GSH which is taken as the comparator with an assigned ratio of 1. Selective data displayed in this table (see supplement Table 3 for full data table). The total listed is for all hospitals.

Discussion

In this study we assessed the number and cost of tests processed pre- and post-implementation of electronic gatekeeping from medical inpatient wards at Groote Schuur Hospital (Cape Town, South Africa). The data was standardised by the calculation of inpatient days as well by using the same NHLS tariffs.

The analytes subject to electronic gatekeeping using MRIs (total protein, total and direct bilirubin, AST, ALT, ALP, GGT, CRP, FBC, HbA1c and TSH) showed a decrease in testing volume. Of these the greatest was with HbA1c (90%) and CRP (82%) and the smallest with FBC (3%) and WCC (2%). This may suggest that these analytes were previously inappropriately repeated before this would be clinically useful.

Although subject to gatekeeping with MRIs, urea and creatinine testing and cost increased by 12% and 21%. Sodium and potassium numbers and cost increased by 18% and 25% respectively. This may suggest that clinicians were still selecting the tests individually to bypass the attempt to discourage testing of the "UEC profile". Other explanations include a change in clinical practice amongst clinicians at the hospital and a possible increase in patient turnover increasing the number of tests attributed to an inpatient day.

Analytes subject to electronic gatekeeping by restricting use to certain specialists are chloride, free T3 and magnesium. Decrease in testing is seen for chloride (91%) followed by FT3 (89%). The cost of magnesium testing increased by 4% despite the restriction and this may suggest that specialist codes were used by non-specialist clinicians to bypass the gatekeeping rule and request the "CMP" profile. Calcium and phosphate testing had no cost-saving. This explanation could also be applied to the Mg: Ca ratio which remained the same.

Procalcitonin testing increased slightly and this might be explained by CRP gatekeeping although the volumes are not nearly comparable with the number previously requested for CRP.

Overall, a 24% cost-saving was made at Groote Schuur Hospital per inpatient day.

Ratios were used to compare testing at Groote Schuur Hospital in the pre- and post-eGK periods. All ratios showed a decrease in testing apart from PCT: FBC+WCC and Mg: Ca which demonstrated a demonstrated an increase. The AST: ALT ratio remained the same in contrast with TP: ALT for which a decrease was noted. The explanation may rest with the fact that liver function tests were restricted according to MRI and when a "LFT" panel was requested then albumin, ALT, ALP, and Tbili would be performed. The AST: ALT and TP:ALT ratios both assess the use of the LFT profile. This may suggest that AST was individually selected along with ALT when requesting this group of tests. Total protein testing is clinically useful when conditions causing an increase in immunoglobulins or a decrease in albumin are suspected. Generally, frequent repetition is not useful and the decrease in this ratio may imply effectiveness of gatekeeping.

The ratios were also used to compare the other national academic hospitals with Groote Schuur by using GSH as the comparator. For the CRP: FBC+WCC ratio, hospital 10 had the highest ratio of 6.50. This ratio suggests that CRP was requested without FBC/WCC testing, which would be expected in a patient with a suspected infection. Hospital 10 performed 93.4 times the number of PCT tests compared to GSH. The ratio appears very high due to the low number of PCT tests performed at GSH and the high number at hospital 10. PCT testing did not increase at GSH, even though it was not subject to eGK. A possible explanation for the increased testing at hospital 10 could be a paediatric ICU using PCT in an antibiotic stewardship program. For the Cl: Na ratio, the majority performed 8.8

times more chloride tests than GSH which implies increased “UEC” profile testing. Chloride testing is useful in clinical circumstances where the anion gap is to be calculated. Most clinical diagnoses will not be influenced by chloride.

The HbA1c: Creat ratio for hospital 6 was 8.3 when compared to GSH. It is possible that glycated haemoglobin was tested more frequently than 3-monthly due to poor adherence to guidelines. Free thyroxine testing was comparable to GSH while hospitals 3, 4 and 6 performed 15, 24 and 19 times more FT3 respectively. The reflexive testing of fT4 when the TSH is abnormal would prevent this. Magnesium: Calcium (Mg: Ca) ratios were similar across the hospitals which likely indicates that CMP profile testing was still being frequently performed without indication.

Recognised limitations of this study include the exclusion of outpatient clinics and surgical wards when calculating the number and costs per test per inpatient day. This would have resulted in exclusion of testing performed by the emergency department prior to admission. Tests were limited to chemical pathology and occasional haematology tests. We did not assess the change in clinician requesting behaviours after implementation of electronic gatekeeping or assess the number of tests rejected or reinstated.

It is not possible from the data to extrapolate the total cost saving to each individual hospital budget or to assess an increase in workload. However, had the GSH eGK rules been implemented on a national scale there would have been a total cost saving of approximately $13 411 873.96 (R103 196 838.80) per year for the national health budget. The study did not address patient outcomes.

Electronic gatekeeping started in the Western Cape province at Groote Schuur Hospital and Tygerberg Hospital. Subsequent to this, eGK was implemented in Gauteng province and the Eastern Cape province, also using facility-specific rules. The variations in test criteria between hospitals created difficulty for the clinicians moving to and working in different facilities within these provinces. In 2016 the Department of Health (DoH) asked the NHLS to extend eGK to all facilities including Primary Health Care facilities. As there are over 5000 DoH facilities, writing facility-specific rules was not feasible. The NHLS expert committees proposed identical gatekeeping rules for non-critical tests based on MRIs. This proposal was discussed with provincial DoH teams. The decision was made to program identical eGK rules for 60 tests, with the ability to program exceptions at facilities where necessary, particularly at academic facilities. Program code for the Laboratory Information System (LIS) software was rewritten to enable implementation of rules at three levels– general, provincial or facility. Studies assessing the expenditure since the implementation may be able to accurately estimate the national savings since the implementation.

In South Africa, 82% of the population or approximately 45 million people, utilise the public health service which relies on the NHLS (21). The NHLS is currently experiencing a shortage in experienced pathologists. There are approximately 237 pathologists working within the NHLS (5.2 per million of the population). In South Africa, pathologists have medical degrees unlike many other countries where academic laboratories are scientist-driven. Pathologists play a vital role in educating clinicians about the appropriate use of laboratory tests based on the clinical findings and this in effect leads to a decrease in costs. The savings which result from electronic gatekeeping could be potentially used to employ an additional 50 pathologists nationally and this could lead to even further decreases in healthcare expenditure.

Conclusion

Laboratory medicine must continually strive to improve standards of healthcare while reducing inefficiency and reducing cost (1) while facing an increase in workload.

This study has shown a decrease in test volumes and cost per inpatient day by the implementation of electronic gatekeeping. Electronic gatekeeping has therefore been shown to be an effective utilisation management tool.

The use of ratios to apply the criteria nationally also showed substantial potential savings.

Utilization management addresses the appropriateness of laboratory testing with a focus on quality, and electronic gatekeeping as a utilization management strategy is relatively easy to implement and manage when the savings are considered. The cost of downstream care and investigations was not assessed, and the potential for saving is therefore likely to be substantially more.

The potential exists for greater savings with stricter rules relating to minimum-retest intervals. The NHLS has subsequently implemented a national electronic gatekeeping strategy using minimum retest intervals. Studies assessing the expenditure since the implementation may be able to accurately estimate the national savings since the implementation.

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ix. Appendices:

a. Supplementary data

Analyte	2008		2011		2012	
	Tests per inpatient day	Cost per inpatient day	Tests per inpatient day	Cost per inpatient day	Tests per inpatient day	Cost per inpatient day
Sodium	0.21	R5.55	0.25	R6.57	0.26	R6.89
Potassium	0.21	R5.55	0.26	R6.91	0.29	R7.56
Chloride	0.05	R0.91	0.004	R0.08	0.003	R0.05
Urea	0.21	R5.56	0.24	R6.21	0.25	R6.69
Creatinine	0.22	R5.72	0.26	R6.90	0.29	R7.49
Total protein	0.09	R2.07	0.02	R0.47	0.03	R0.57
Albumin	0.12	R4.05	0.06	R2.01	0.07	R2.27
Total bilirubin	0.12	R3.59	0.06	R1.92	0.07	R2.05
Direct bilirubin	0.10	R2.36	0.03	R0.79	0.04	R1.02
ALT	0.13	R4.94	0.08	R3.09	0.08	R3.15
AST	0.11	R4.46	0.06	R2.36	0.06	R2.47
ALP	0.12	R4.62	0.06	R2.38	0.07	R2.66
GGT	0.11	R4.52	0.06	R2.27	0.06	R2.38
CRP	0.04	R3.17	0.01	R0.56	0.01	R0.98
PCT	0.01	R1.71	0.002	R0.70	0.01	R2.06
FBC	0.19	R9.45	0.18	R9.21	0.16	R8.12
WCC	0.01	R0.18	0.01	R0.18	0.01	R0.20
HbA1c	0.003	R0.26	0.0004	R0.03	0.002	R0.12
Glucose	0.012	R0.33	0.004	R0.22	0.004	R0.09
TSH	0.01	R1.88	0.01	R1.19	0.01	R1.30
Free T4	0.01	R1.15	0.003	R0.35	0.002	R0.30
Free T3	0.002	R0.29	0.0002	R0.03	0.0003	R0.04
Ca	0.05	R1.26	0.05	R1.26	0.05	R1.25
Mg	0.04	R1.14	0.05	R1.19	0.05	R1.21
Phos	0.04	R1.13	0.04	R1.13	0.04	R1.14

Table 1. Data from 2011 and 2012. Similar test numbers and cost.

	Ratio	Absolute number of tests	Cost USD	Cost ZAR	Cost-saving USD	Cost-saving ZAR
CRP			**10.24**	**78.81**	**2 870 347**	**22 085 707**
Groote Schuur	0.08 (1.0)	14 542	148 945.90	1 146 055		
Hospital 2	1.9	13 500	138 273.20	1 063 935	64 330.33	494 985.80
Hospital 3	2.0	12 700	130 079.30	1 000 887	65 363.20	502 933.30
Hospital 4	2.7	20 201	206 908	1 592 041	130 558.20	1 004 572
Hospital 5	2.7	29 594	30 311.40	2 332 303	192 489.40	1 481 098
Hospital 6	3.8	32 136	329 151.80	2 532 638	241 843.60	1 860 851
Hospital 7	4.8	93 003	952 579.80	7 329 566	752 877.50	5 792 970
Hospital 8	5.6	81 402	833 757	6 415 292	684 871.80	5 269 704
Hospital 9	6.1	48 542	497 189.60	3 825 595	420 698.90	3 237 042
Hospital 10	6.5	36 613	375 007.30	2 885 471	317 313.90	2 441 552
PCT			**43.72**	**336.41**	**3 224 952**	**24 814 195**
Groote Schuur	0.004 (1.0)	790	34 539.70	265 763.90		
Hospital 2	12.7	4 971	217 338	1 672 294	200 153.90	1 540 072
Hospital 3	10.5	4 174	182 492.20	1 404 175	165 145.20	1 270 700
Hospital 4	0.5	216	9 443.80	72 664.56		
Hospital 5	0.0	1	43.72	336.41		
Hospital 6	32.8	15 080	659 315.50	5 073 063	639 219.80	4 918 438
Hospital 7	4.1	3 834	167 627	1 289 796	126 237.60	971 327.70
Hospital 8	12.4	7 492	327 559.10	2 520 384	301 055.80	2 316 455
Hospital 9	43.4	15 734	687 909.20	5 293 075	672 067.80	5 171 184

Hospital 10	93.4	25 919	1 133 210	8 719 411	1 121 072	8 626 019
Cl			**2.44**	**18.75**	**1 955 233**	**15 044 418**
Groote Schuur	0.12 (1.0)	17 339	42 252.10	325 106.30		
Hospital 2	8.8	75 360	183 639.10	1 413 000	162 673.30	1 251 680
Hospital 3	8.8	65 884	160 547.80	1 235 325	142 213.50	1 094 253
Hospital 4	8.7	87 512	213 251.40	1 640 850	188 846.50	1 453 068
Hospital 5	3.8	47 642	116 095.20	893 287.50	85 826.70	660 388.20
Hospital 6	8.8	104 153	253 802.60	1 952 869	224 918.50	1 730 622
Hospital 7	8.7	234 395	571 179.60	4 394 906	505 797.90	3 891 831
Hospital 8	8.8	169 130	412 140.20	3 171 188	365 101.50	2 809 251
Hospital 9	8.7	107 644	262 309.60	2 018 325	232 046.70	1 785 469
Hospital 10	5.4	24 082	58 683.60	451 537.50	47 808.20	367 856.90
Urea			**3.41**	**26.27**	**983 507.70**	**7 567 539**
GSH	0.58 (1.0)	138 514	472 908.20	3 638 763		
Hospital 2	1.5	75 766	258 676.80	1 990 373	84 812	652 580.80
Hospital 3	1.2	67 068	228 980.50	1 761 876	38 954.90	299 735.80
Hospital 4	1.5	89 167	304 429.90	2 342 417	94 787.95	729 340.10
Hospital 5	1.1	131 063	447 469.30	3 443 025	53 432.90	411 135.90
Hospital 6	1.6	104 307	356 120.20	2 740 145	139 363.20	1 072 321
Hospital 7	1.3	237 750	811 715.20	6 245 693	194 114.20	1 493 600
Hospital 8	1.4	178 935	610 911.70	4 700 622	164 659.30	1 266 961
Hospital 9	1.4	119 379	407 578.30	3 136 086	104 751.50	806 003.90

Hospital 10	1.6	82 490	281 633.60	2 167 012	108 631.80	835 861
AST			**5.11**	**39.34**	**382 118.30**	**2 940 186**
GSH	0.59 (1.0)	49 289	252 004	1 939 029		
Hospital 2	0.3	12 549	64 160.30	493 677.70		
Hospital 3	1.2	33 806	172 842.80	1 329 928	29 464.80	226 715.40
Hospital 4	1.1	36 128	184 714.70	1 421 276	21 760.10	167 432
Hospital 5	0.7	18 459	94 376.90	726 177.10		
Hospital 6	1.8	65 873	336 794.40	2 591 444	146 417.80	1 126 603
Hospital 7	1.0	71 341	364 751.10	2 806 555		
Hospital 8	1.1	63 024	322 228.10	2 479 364	28 572.90	219 852.50
Hospital 9	1.4	55 311	282 793.20	2 175 935	81 531.20	627 336.90
Hospital 10	1.7	34 977	178 829.80	1 375 995	74 371.40	572 246.20
TP			**2.93**	**22.58**	**624 880.10**	**4 808 102**
GSH	0.24 (1.0)	19 714	57 852.45	445 142.10		
Hospital 2	4.1	53 733	157 684.20	1 213 291	119 239.50	917 481
Hospital 3	3.1	33 133	97 231.70	748 143.10	65 394.65	503 175.20
Hospital 4	2.9	35 085	102 960	792 219.30	67 148.45	516 669.60
Hospital 5	0.8	8 594	25 219.80	194 052.50		
Hospital 6	4.5	65 556	192 379.80	1 480 254	149 770.30	1 152 398
Hospital 7	2.1	60 162	176 550.60	1 358 458	93 133.70	716 611.30
Hospital 8	2.6	57 152	167 717.50	1 290 492	102 068.40	785 359.10
Hospital 9	0.4	11 241	32 987.70	253 821.80		

Hospital 10	3.1	14 113	41 415.80	318 671.50	28 125.15	216 407.20
HbA1c			**9.61**	**73.96**	**961 627.50**	**7 399 184**
GSH	0.04 (0.1)	8 851.61	85 077	654 620		
Hospital 2	0.6	2 289	22 002.20	169 294.40	11 588.20	
Hospital 3	1.3	5 017	48 224.10	371 057.30	46 330.80	89 164.50
Hospital 4	2.2	8 888	85 432.70	657 356.50	73 153.10	356 489.70
Hospital 5	2.0	15 431	148 324.90	1 141 277	355 027	562 872.40
Hospital 6	8.3	41 992	403 632.90	3 105 728	97 621.20	2 731 733
Hospital 7	1.9	21 590	207 526	1 596 796	274 059.60	751 140.40
Hospital 8	4.2	37 514	360 589.70	2 774 535	58 363.60	2 108 734
Hospital 9	1.9	12 572	120 843.80	929 825.10	45 484	449 075
Hospital 10	2.4	8 225	79 059.80	608 321	11 588.20	349 974.10
T4			**16.60**	**127.75**	**1 206 955**	**9 286 843**
GSH	0.38 (1.0)	9 597	159 338	1 226 017		
Hospital 2	1.3	1	16.60	127.75	3.90	29.90
Hospital 3	2.1	3 059	50 788.27	390 787.30	26 371.65	202 915.10
Hospital 4	2.2	11 008	182 764.70	1 406 272	99 829	768 128.50
Hospital 5	0.8	9 344	155 137.50	1 193 696		
Hospital 6	2.4	70 982	1 178 507	9 067 951	676 086.20	5 202 104
Hospital 7	1.2	13 041	216 518.40	1 665 988	38 415.20	295 583.70
Hospital 8	1.9	16 938	281 219.90	2 163 830	129 703.60	997 996.40

Hospital 9	1.8	11 920	197 906.60	1 522 780	89 958.90	692 183
Hospital 10	2.1	16 760	278 264.60	2 141 090	146 586.70	1 127 903
T3			**16.60**	**127.75**	**1 106 740**	**8 515 743**
GSH	0.03 (1.0)	769	12 767.63	98 239.75		
Hospital 2	-	-	-	-	-	-
Hospital 3	15.3	2 131	35 380.78	272 235.30	33 072.80	254 476.50
Hospital 4	24.6	10 264	170 412.20	1 311 226	163 471.10	1 257 818
Hospital 5	2.9	2 538	14 360.10	324 229.50	27 778.10	213 736.60
Hospital 6	19.3	53 014	880 186.20	6 772 539	834 643.50	6 422 113
Hospital 7	1.1	769	11 550.70	98 239.75	1 216.90	9 363.60
Hospital 8	3.5	3 213	14 951.06	410 460.80	38 394	295 420.70
Hospital 9	1.5	924	10 209.12	118 041	5 132	39 487.50
Hospital 10	1.3	800	10 250.67	102 200	3 031.65	23 326.80
T3			**16.60**	**127.75**		
GSH	0.08 (1.0)	769				
Hospital 2	-	-	-	-	-	-
Hospital 3	8.7	2 131				
Hospital 4	11.6	10 264				
Hospital 5	3.4	2 538				
Hospital 6	9.3	53 014				
Hospital 7	0.7	769				
Hospital 8	2.4	3 213				

Hospital 9	1.0	924				
Hospital 10	0.6	800				
Mg			**3.41**	**26.27**	**95 513.44**	**734 922.30**
GSH	0.91 (1.0)	30 913	105 541.80	812 084.50		
Hospital 2	1.1	39 983	136 508.10	1 050 353	11 895.10	91 526
Hospital 3	1.1	10 901	37 217.70	286 369.30	3 549.60	27 312.30
Hospital 4	1.1	9 324	31 833.60	244 941.50	2 073.20	15 952
Hospital 5	1.0	40 593	138 590.80	1 066 378	3 381.90	26 021.50
Hospital 6	1.1	49 505	169 017.70	1 300 496	18 881.70	145 284
Hospital 7	1.1	70 340	240 151.60	1 847 832	18 816.20	144 780.30
Hospital 8	1.1	86 313	294 685.90	2 267 443	21 046.30	161 939.80
Hospital 9	1.0	38 658	131 984.40	38 658		
Hospital 10	1.1	38 745	132 281.40	1 017 831	15 869.40	122 106.30
Total					13 411 873.96	103 196 838.80

Table 2. Ratios of Groote Schuur Hospital and other national academic hospitals. Hospitals 2 – 10 are compared to GSH which is taken as the comparator with an assigned ratio of 1.

b. Instructions to authors

AUTHOR CONTRIBUTION REQUIREMENTS

Clinical Chemistry follows the recommendations for authorship set out by The International Committee of Medical Journal Editors (ICMJE). In accordance with these recommendations, manuscripts are considered for publication with the understanding that each listed author must meet the following criteria:

1. Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND
2. Drafting the work or revising it critically for important intellectual content; AND
3. Final approval of the version to be published; AND
4. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

MANUSCRIPT GUIDELINES

- MS Word document (.doc or .docx) is required for all submissions.
- All figures must be uploaded separately as Image Files in Tagged Image File Format (.tiff), Encapsulated Postscript (.eps) or PowerPoint (.ppt) with embedded fonts.
- All submissions must be double-spaced, 1-inch margin, twelve-point font size in Arial, Helvetica, Times New Roman and Symbol font (for non-text characters).
- All submissions must be page numbered.
- All submissions must have line numbers included in the text.
- Do not use headers or footers.
- Use standard abbreviations and define all nonstandard abbreviations.
- All submissions require a title page.
- Reporting of Concentration Units:

1. Analyte concentrations will be expressed in the text in the traditional mass unit (mg/dL, ng/ml, and so forth) followed by the SI unit in parentheses. Exceptions would include those analytes in which SI units are used globally, such as electrolytes (use mmol/L for sodium, potassium, chloride, and CO_2 values), or cases in which the traditional unit and the SI unit differ by only a factor of 1000 in both the numerator and denominator (e.g., ng/mL vs µg/L). In such cases, the unit of measure consistent with common practice will be used.
2. The unit of measure mg/L should be used only when referring to SI units or when national or international guidelines require or recommend that the concentration of an analyte be expressed in that unit of measure, such as for high-sensitivity C-reactive protein. The unit of measure U/L will be used for most enzyme activities.
3. Only traditional units will be used for tables and figures in the printed version of a report; SI conversion factors will be provided in legends. All tables and figures will also be presented in SI units. These tables and figures will be made available in online supplements to published articles and letters. Authors will provide both versions before final acceptance of a manuscript. SI units are available at Bureau International des Poids et Mesures.

- Supplemental Data are accepted for online publication only and are limited by submission types (See Types of Submissions for details).

- Follow the guidelines for length restrictions, abstract, reference, table and figure, and supplemental data limits as outlined in the chart below:

Type of Submission	Word Limit*	Structured** (S) or Unstructured (U) Abstract: Word Limit	Maximum Number of References	Total Number of Tables/Figures	Supplemental Data Permitted
Article	3,500	S: 250	40	6	Yes

*Word limit consists of the body of the manuscript only; it does not encompass the title page, abstract, acknowledgments, references, tables, figure legends, figures, or Clinical Case descriptions, questions, and points to remember.
**Structured abstracts contain the headings (1) BACKGROUND, (2) METHODS, (3) RESULTS, (4) CONCLUSIONS for all applicable article types except for Reviews and Mini-Reviews. Abstracts for Reviews and Mini-Reviews contain the headings (1) BACKGROUND, (2) CONTENT, (3) SUMMARY.
***If a figure accompanies the paper, the image should not be multipart (i.e., Fig. 1A, 1B, 1C, Part 1, Part 2).

http://clinchem.aaccjnls.org/content/information-authors

c. HREC approval letter

UNIVERSITY OF CAPE TOWN
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08 July 2015

HREC REF: 492/2015

Dr G van der Watt
Division of Chemical Pathology
NHLS
NGSH

Dear Dr van der Watt

PROJECT TITLE: ASSESSMENT OF THE EFFECTIVENESS OF ELECTRONIC GATEKEEPING AS A UTILISATION MANAGEMENT TOOL AT GROOTE SCHURR HOSPITAL. (Mmed candidate- Michelle Bosman

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

Approval is granted for one year until the 30th July 2016.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the following student:- Michelle Bosman is also involved in this project.

Please quote the HREC reference no in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

Hrec/ref:492/2015

d. DOH approval letter

Western Cape Government
Health

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NEW MAIN BUILDING

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Dear Dr Van Der Watt

RESEARCH PROJECT: Assessment Of The Effectiveness Of Electronic Gatekeeping As A Utilisation Management Tool At Groote Schuur Hospital (Mmed Michelle Bosman)

Your recent letter to the hospital refers.

You are hereby granted permission to proceed with your research and is valid until **30 July 2016**.

Please note the following:

a) Your research may not interfere with normal patient care.
b) Hospital staff may not be asked to assist with the research.
c) No additional costs to the hospital should be incurred i.e. Lab, consumables or stationary may be used.
d) **No patient folders may be removed from the premises or be inaccessible.**
e) Please introduce yourself to the person in charge of an area before commencing.
f) Please discuss the study with the HOD before commencing.
g) Please provide the research assistant/field worker with a copy of this letter as verification of approval.
h) Confidentiality must be maintained at all times.
i) Should you require additional research time beyond the stipulated expiry date, please apply for an extension.
j) **Once research is complete, please submit a copy of the publication or report.**

I would like to wish you every success with the project.

Yours sincerely

DR BERNADETTE EICK
CHIEF OPERATIONAL OFFICER
Date: 30March 2016

BE/vms

C.C. Mr. L. Naidoo, Dr B. Jacobs, Dr H. Vreede

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