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RESEARCH ARTICLE

Cost effectiveness of Electronic Gate Keeping (EGK) system on laboratory tests demand at a rural academic hospital in Eastern Cape, South Africa: a cross sectional study [version 1; peer review: awaiting peer review]

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Abstract

Background: Monitoring laboratory expenditure is crucial to ensure that laboratory services remain sustainable and affordable. In South Africa, the National Department of Health (NDoH) and its partner, the National Health Laboratory Services (NHLS) collaborated to introduce Electronic Gate Keeping (EGK) systems across the country. This study estimated the cost-effectiveness of EGK on laboratory tests requested at a rural academic hospital in the Eastern Cape province of South Africa.

Methods: The methodological approach involved the use of a cross-sectional study design. For 24 months (June 2015 to May 2017), data on the number and types of laboratory tests initially requested along with those rejected because there were unnecessary was obtained. Data management and cost effectiveness analysis to estimate cost savings due to EGK on laboratory test demands were carried out using MS Excel and Stata software. There were 28 types of tests requested, of which 22 were chemical tests, two were haematological tests, and four were serological tests.

Results: Out of 448 028 tests requested, 17,480 (3.9%) were rejected after being identified as unnecessary through the EGK system. This rejection rate of 3.9% generated cost savings of USD 51,967.07. The top three tests that generated the most savings were the c-reactive protein (USD 6,077.68), free thyroxine (USD 5,199.92) and hepatitis A IgM (USD 3,813.61).

Conclusions: The study demonstrates that the introduction of EGK has positive spinoffs; it reduced costs, strengthened the dialogue

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between clinicians and pathologists allowing a platform for continuous education, teaching and learning.

Keywords
laboratory tests, electronic gate keeping, cost savings, rejected tests, rural academic hospital, South Africa

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Background

Laboratory medicine, a branch of medicine and a component of the healthcare delivery system that provides diagnostic services such as laboratory investigations, the results of which are critical to clinicians' disease management decisions, is unfortunately affected by unnecessary laboratory investigations that are not required but repeatedly requested due to irregular documentation by clinicians.[1–3] These unnecessary laboratory test requests could indicate a request made for the wrong patient, at the wrong time, or for the wrong disease condition.[4] A B-type natriuretic peptide (NT-proBNP) test, for example, is useful as a diagnostic test for congestive heart failure patients. However, evidence suggests that while there is no guideline for repeated NT-proBNP measurements in the management of heart failure, it should be measured only once except in certain pragmatic situations such as clinical deterioration. As a result, requesting this test repeatedly, such as on a daily basis, is not the best course of action for determining the severity or stability of a heart condition.[4] A rippling effect of this is that it leads to an increase in patient discomfort, duplication of laboratory investigations and monetary costs associated with the use of kits, staff and time.[3–5] Consequently, countries have taken decisive action to review, develop robust and multifaceted strategies to tackle waste associated with repeated laboratory investigation and adopt those that work best in their environment.[4,6–8] These initiatives are a response to the recognition of the need for an urgent reduction in unnecessary laboratory test requests and costs.[9,10]

In 2010, the South African National Department of Health (NDoH) and its partner - National Health Laboratory Services (NHLS), collaborated to develop a sustainable and affordable Electronic Gate Keeping (EGK) system. The EGK is a demand management system, defined as a full electronic stop (system-based intervention) to reduce overutilization on some laboratory test orders.[11] It is a Laboratory Interface System (LIS) used to approve or reject laboratory tests based on the protocols for patient management devised by hospital management; the NHLS translates the rules into LIS. Upon a rejection of a test, an SMS alert is sent to the requesting medical officer notifying them that a test has been rejected. The SMS reads "Test automatically rejected on the basis of hospital electronic gate keeping rules". If it is clinically necessary for the test to be performed, the rejection can only be reversed by providing a valid approval number to the laboratory, this must be done before the stability of the test is exceeded.

The primary application of this demand management is to ensure appropriate laboratory requesting and testing; for the right patient at the right time. For example, requesting a prostate specific antigen test for a male patient over 40 years for screening every six months if the previous result was normal, is appropriate and necessary testing. Since the inception of EGK in South Africa from 2011 to date, only two published articles have evaluated the EGK system. The two previous studies by Smit *et al.*[4] in 2015 and Pema *et al.*[8] in 2017 were conducted in urban hospital settings in the Western Cape and Gauteng provinces respectively. However, there was constrasting findings on the cost effectiveness of EGK. Therefore, this study builds on the previous studies' work and aims to provide evidence on the cost-effectiveness of the EGK system on laboratory tests requested at a rural academic hospital in the Eastern Cape province of South Africa.

Methods

Ethical considerations

The Walter Sisulu University Human Research Ethics and Biosafety Committee in South Africa reviewed and approved this study, which was assigned the ethics number 062/2019 on 05 November 2019.

Study design

The study used a descriptive cross-sectional study design to retrospectively audit EGK subjected tests at the NHLS in Mthatha by Nelson Mandela Academic Hospital for 24 months, from 2nd June 2015 to 31st May 2017. Through this audit, there was an estimate of cost savings from the unnecessary tests identified and rejected by the EGK system.

Study setting

The study was conducted at the Nelson Mandela Academic Hospital (NMAH), a tertiary teaching 507-bed hospital affiliated with Walter Sisulu University medical school and Lilitha Nursing training college. The hospital provides teaching and training to student medical doctors and registrars, and nurses. NMAH boasts specialized medical services, delivering comprehensive clinical care to inpatients and outpatients with complex medical conditions. The hospital is located in the rural area of the Eastern Cape Province, South Africa, in the OR Tambo district municipality.[12]

Sample and data collection

The data collected from 28 requested laboratory tests is shown in Table 1. The tests are billed on the National Tertiary Service Grant and categorized as high-volume tests, while others were high-cost tests. The sample for the study were medical laboratory tests subjected to EGK, any tests that were not subjected to EGK were excluded. Data collection entailed a review of pre-existing NHLS monthly electronically generated EGK rejection reports routinely supplied to the NMAH for monitoring and evaluation during the study period.

Table 1. List of test and EGK applied rules.

Test set and abbreviations	EGK rule	Category of doctors
Haematology		
Full blood count and Differential count	Allow first test for all levels doctors.	**Level 0**
	Allow repeat after 22 hours for inpatients and 2 weeks for outpatients for all levels.	Not registered as NMAH requesting doctor
Chemistry		
Creatinine and Urea	Allow first test for all levels doctors.	**Level 1**
	Allow repeat after 22 hours for inpatients and 2 weeks for outpatients for all levels.	Medical Intern
Glycated haemoglobin (HbA1C)	Allow first test for all levels doctors. Allow repeat once for inpatients and after 3 months for outpatients.	
Calcium, Magnesium, Phosphorus	Allow test for level 5 doctors only.	**Level 2**
	All other levels will motivate for this test and or at the discretion of a level 5.	Medical Officer (junior)
Total protein, Albumin	Allow first test for all levels doctors.	**Level 3**
	All other levels will motivate for this test and or at the discretion of a level 5.	Medical Registrar
Total Bilirubin, Direct Bilirubin,	Allow first test for all levels doctors.	**Level 4**
Alanine Transaminase, Aspartate Transaminase	Allow repeat if previous results were abnormal after 24 hours for inpatients.	Medical Officer (senior)
Alkaline Phosphatase, Glutamyl Transpeptidase	Allow repeat if previous results were abnormal after 2 weeks for outpatients.	
Total Cholesterol, Triglycerides,	Allow first test for all levels doctors.	**Level 5**
High Density Lipoproteins	Allow repeat once for inpatients and after 6 months for outpatients.	Consultants/specialists
C-reactive protein (CRP)	Allow first test for all levels doctors. Allow repeat for level 5 only	
Thyroid Stimulating Hormone (TSH)	Allow first test for all levels doctors. Allow repeat once for inpatients and after 2 months for outpatients.	
Prostate Specific Antigen	All levels to request the test for male patients of 45 years of age and more only. Allow repeat every 6 months.	
Serology		
Hepatitis A-IgM	Allow test for level 5 doctors only. All other levels will motivate for this test and or at the discretion of a level 5.	
Hepatitis B Surface Antigen and Antibody,	Allow first test for all levels.	
Hepatitis C Antibody	Allow repeat for level 5 only.	
Any other repeat other than the mentioned will be motivated for by the requesting medical officer and or at the discretion of level 5.		

Source: Nelson Mandela Academic Hospital.

Data management and analysis

Data was managed and analysed using Microsoft Excel. Data analysis was mainly descriptive and it involved the use of summaries (such as counts, frequency, differences, multiplication) and graphs. Variables included the number of EGK subjected tests requested, the number of EGK subjected tests rejected for the estimation of test rejection and the cost savings in dollars. The cost savings were calculated by obtaining the number of rejected tests, multiplied by the cost of the rejected test charged at an official rate by the laboratory to perform the test.

$$\text{Cost savings} = \text{Number of rejected tests} \times \text{cost of the rejected tests}$$

All monetary values were computed from South African rands to United States Dollars (USD) using a conversion rate of ZAR 15.53 to 1 USD as per the South African Reserve Bank exchange rate on 19th November 2020.[13] Further, the Consumer Price Index method was used to calculate the inflation rate since the USD in 2015 (USD 51,967.07) had the same purchasing power as in 2020 (USD 57,091.27). Considering the total inflation rate from 2015 to 2020 to be 9.9%, we interpreted the cost savings as preventative expenditure.

Results

Medical laboratory tests/investigations requested during the study period

Table 1 presents the laboratory tests requested duriing the 24 months study period (2nd June 2015 to 31st May 2017) and the EGK rules applied to deterrmine which should be processed or rejected. A total of 448,028 EGK subjected tests were requested during the study period (Table 1). The total number of tests was 27 and out of these; 21 were chemistry, two haematology and four serology tests.

Table 2. Cost effectiveness of lab expenditure in US Dollars.

Test set (abbreviations)	Requested	Rejected	%	Savings (USD)
Creatinine (CREA)	77068	331	0.4	573.13
UREA	76805	379	0.5	662.73
Glycated haemoglobin (HBA1C)	1628	56	3.4	265.24
Calcium (CA)	9938	1830	18.4	3035.34
Magnesium (MG)	9136	1653	18.1	2872.94
Phosphate (PHOS)	8723	1575	18.1	2735.22
Total protein (TP)	18052	898	5	1343.64
Albumin (ALB)	22602	1476	6.5	3476.52
Total bilirubin (TBIL)	19949	1073	5.7	2172.72
Conjugated bilirubin (CBIL)	16438	539	3.3	833.71
Alanine Transaminase (ALT)	25010	1178	4.7	3085.82
Aspartate Transaminase (AST)	20753	695	3.4	1803.21
Alkaline Phosphatase (ALP)	15110	597	4	1474.19
Gamma Glutamyl Transpeptidase (GGT)	18057	712	4	1851.78
Cholesterol (CHOL)	1139	35	3.1	91.37
Triglycerides (TRIGS)	855	237	27.7	91334
High Density Lipoprotein (HDL)	24	10	41.7	38.77
C-reactive protein (CRP)	20633	1462	7.1	6077.68
Prostate Specific Antigen (PSA)	1621	118	7.3	886.98
Thyroid Stimulating Hormone (TSH)	3260	166	5.1	1635.81
Free thyroxine (FT4)	2548	617	24.2	5199.92
Tri-iodothyronine (FT3)	992	249	25.1	2070.4
Full blood count (FBC)	57487	266	0.5	867.02
Differential count (DIFF)	12875	75	0.6	132.74
Hepatitis A IgM (HAM)	1196	535	44.7	3813.61
Hepatitis B Surface Antigen (HBSAG)	2829	366	12.9	2101.69
Hepatitis B Surface Antibody (HBSAB)	1877	152	8.1	508.4
Hepatitis C Antibody (HCAB)	1423	200	14.1	1443.15
Total	448028	17480	3.9	51967.07

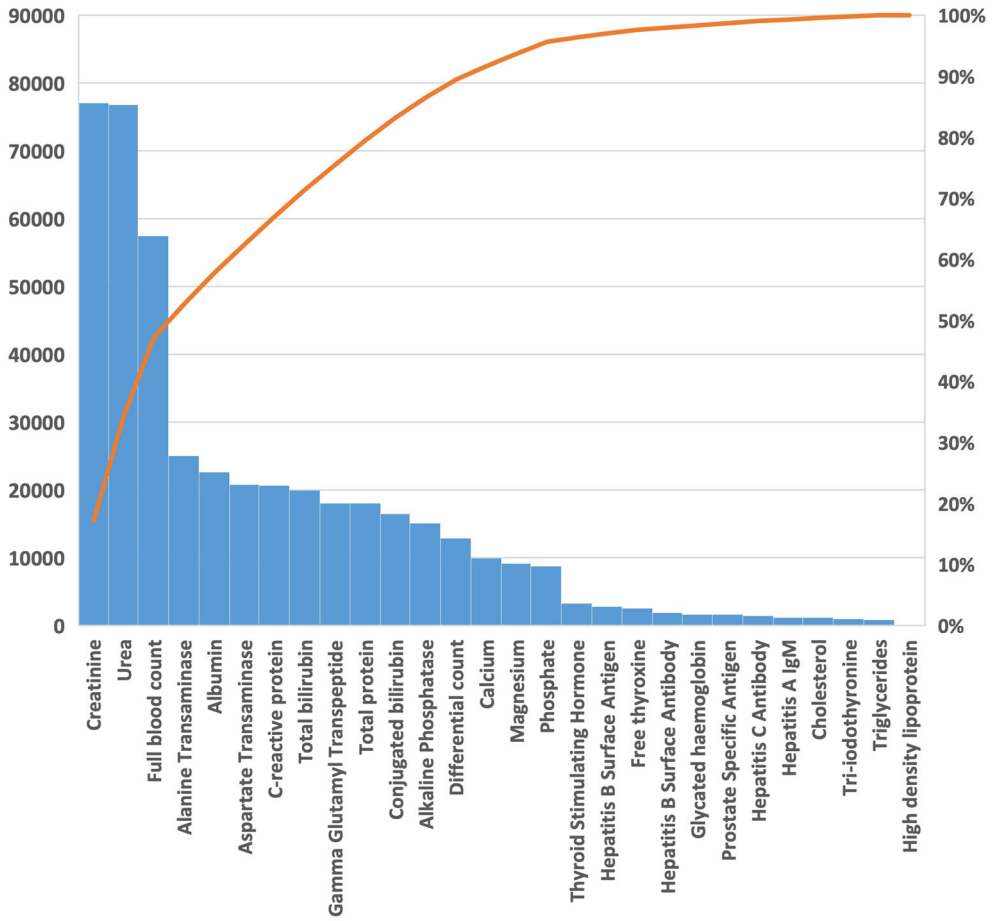

Figure 1. Top requested tests by quantity.

The extent of requested tests rejected and the rejection rate

A total 17,480 tests were rejected and or prevented by EGK from being analyzed with a rejection rate of 3.9% (Table 2). Creatinine, urea and full blood count were the top three tests that were requested respectively (Figure 1). Calcium, magnesium and phosphate were the top three tests that were rejected respectively (Figure 2).

Cost effectiveness from the EGK system as an intervention

The top three tests that generated the most savings are c-reactive protein (USD 6,077.68), free thyroxine (USD 5,199.92) and hepatitis A IgM (USD 3,813.61) (Figure 3). The total cost savings as a result of the EGK system was USD 51,967.07.

Discussion

This study purposed to determine the cost savings obtained from tests rejected by the EGK system; a demand management tool (National Health Laboratory Service 2012). This is the first study that investigated the cost effectiveness of EGK, particularly in a rural setting in South Africa. In this paper, the majority of the 28 types of tests audited were low cost tests, i.e. were above USD 1.50 but less than USD 5.30 per test; and the minority of the tests studied that were high cost tests, i.e. were above USD 7.50 but less than USD 11.00 per test. We also found that the test that generated the highest savings was a low cost c-reactive protein (CRP) test; followed by free thyroxine (FT4) and hepatitis A IgM (HAM) which are both in the category of high cost tests. The top 15 tests that were rejected and thereby generated the highest cost savings were tests that are usually requested in a bundle with other accompanying tests; except for the CRP. In particular, the FT4 which generated the second highest cost savings in our study is a test that is often requested in a bundle, i.e. a thyroid function test, comprising a thyroid stimulating hormone (TSH) and tri-iodothyronine (FT3). Similarly, HAM generated the third highest cost savings because this test is usually requested in a bundle as part of a hepatitis screen, which is unnecessary most times, not unless it is clearly marked and requested on the laboratory form.

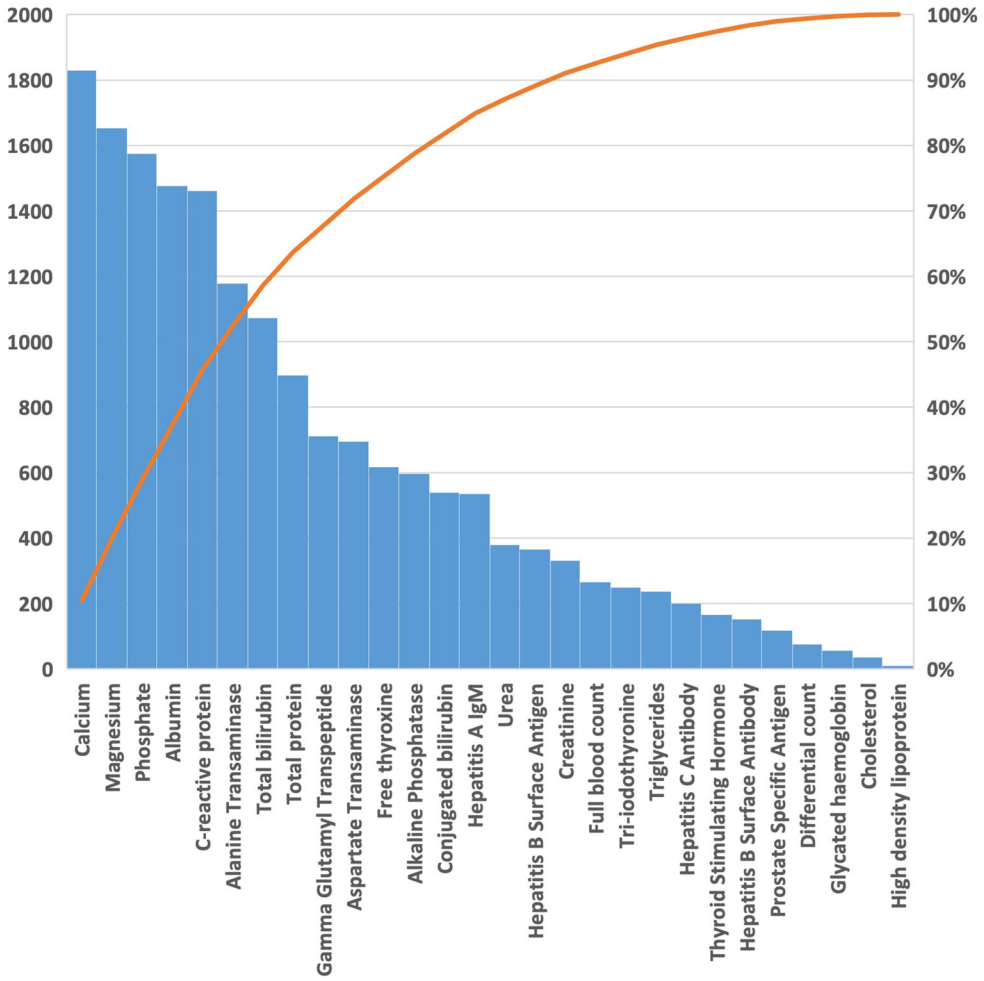

Figure 2. Top rejected tests by electronic gate keeping (EGK).

When we compare our study findings with that from the only two other studies that investigated the same intervention in South Africa,[4,8] we found that the tests audited were quite similar; i.e. were basic, routine, frequently requested tests and as Konger *et al.*[14] would say, 'these tests were unnecessary and overused'. Furtheron, while we studied 28 tests, Smit *et al.*[4] and Pema *et al.*[8] studied 26 and 31 tests respectively. Our study revealed test requests of 448,028, while the number of requested tests by Smit *et al.*[4] was 68,480 and Pema *et al.*[8] was 1,493,965. The difference in the number of tests requested between our study and these studies could be due to the hospital facility's population coverage, which is much larger than our study setting, which serves a rural district with just over 5 million. Furthermore, the meagre number of test requests in the study by Smit *et al.*[4] compared to our study could be justified and linked to their short six-month study period; thus, we presume that if their study were more than six months, more tests would have been requested.

Based on the top three repertoire of tests requested in this study compared to other studies, creatinine, urea and full blood count were the three most requested in this study. On the other hand, Smit *et al.*[4] demonstrates calcium, magnesium and phosphate while Pema *et al.*[8] reports the top most requested tests as urea and electrolytes, calcium, magnesium and phosphate. Parallel to the number of tests requested between our study and the two other studies, our study presented a rejection rate of 3.9%, which was found to be insignificantly higher (0.72%) than the rejection rate reported by Pema *et al.* at 3.18%, but significantly lower (2.9%) than the rejection rate reported by Smit *et al.* at 6.7%. The varying degree of rejection rate, especially between our study and Smit *et al.,* may be linked mainly to our higher number of test requests compared to theirs and/or possibly the criteria of the EGK test rules applied between the two hospital settings. Regarding the cost savings, our study found the top three tests that generated the most savings to be single tests, i.e. CRP, FT4 and HAM respectively, whereas Smit *et al.* reported their cost savings to be generated by the thyroid function panel, liver function panel and CRP respectively. The CRP was the common test between the two studies. The tests that generated the greatest cost savings as reported by Pema *et al.* were urea and electrolytes panel, thyroid function tests and glycated hemoglobin. There were no similarities regarding the tests that generated cost savings between these two studies. In

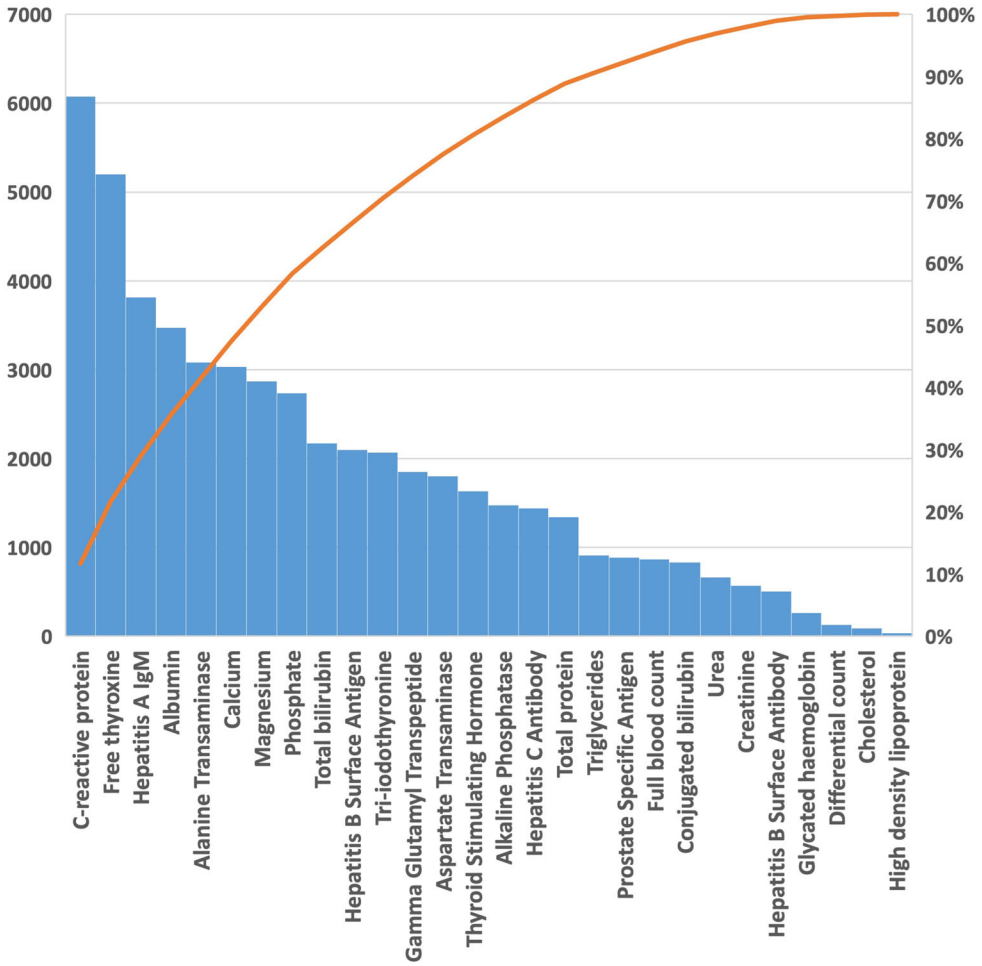

Figure 3. Proportion of tests with cost savings in dollars.

contrast, while our greatest cost savings were obtained on single tests, Smit *et al.* and Pema *et al.* reported having obtained theirs mainly on test panels and or profiles.

Limitation

The first limitation of the study is the fact that the clinical and patient outcomes of the rejections was not assessed, and therefore it is not known how much of patient management was affected by the rejections. Having said that, it should also be emphasized that EGK was not a closed system that rejected tests and not looked back, but rather opened a window of opportunity and allowed tests to be restored and analyzed if such a request had been submitted by the clinician with a clinical justification. Secondly, this study did not calculate the restored tests after they were initially requested and rejected respectively. This exercise would have provided useful information of how critical these tests were or not for patient management.

Conclusion

Based on these findings, we suggest that requesting tests in a bundle is discouraged as this may contribute to unnecessary testing that may not be clinically indicated. Besides, another resultant effect of requesting tests in a bundle is wasted resources accompanied by increased expenditure and increased laboratory workload amongst other things. So we advocte for selective testing to be the most encouraged type of medical laboratory investigations. More importantlly we note that to use a single intervention method, like we did with the EGK system, to address unnecessary laboratory testing might not have a great impact and/or result; but rather is a multifaceted approach that should be used for better outcomes. Therefore this novel EGK sytem as an intervention should be used in conjunction with continuous education focusing on the importance of making mindful laboratory test requesting, selective testing, the costs of individual tests and the impact these have on expenditures when they are requested unnecessarily; following of recommended guidelines on the

management of acute and chronic diseases. Lastly, additional studies are recommended to assess the cost effectiveness of introducing EGK at across all facilities nationwide.

Data availability

Underlying data

Figshare: 'Cost effectiveness of electronic gate keeping (EGK) system on laboratory tests demand at a rural academic hospital in Eastern Cape, South Africa'. https://doi.org/10.6084/m9.figshare.19739260.[15]
This project contains the following underlying data:

- Zol M1_data1.xlsx (description of the data - The data provided lists of test demanded and costs for medical laboratory investigations on behalf of patients at a rural academic hospital in Mthatha, Eastern Cape, South Africa. The essense of the data is to enable assessment of the cost effectiveness of medical laboratory expenditures.)

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