ORIGINAL ARTICLE

The cost of time: A randomised, controlled trial to assess the economic impact of upfront, point-of-care blood tests in the Emergency Centre

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A B S T R A C T

Introduction: Time and cost constraints abound in the Emergency Centre (EC). These resource-constraints are further magnified in low- and middle-income countries (LMIC). Almost half of all patients presenting to the EC require laboratory tests. Unfortunately, access to laboratory services in LMIC is commonly inadequate. Point-of-Care (POC) tests may assist to avert this shortcoming. The aims of this study were to evaluate the cost effectiveness of upfront POC blood tests performed prior to doctor assessment compared to the standard EC workflow.
Methods: A secondary analysis was performed on data from a prospective, randomised, controlled trial where patients with abdominal/chest symptoms or generalised body pain/weakness followed either the normal EC workflow pathway or one of two enhanced workflow pathways with POC tests (i-STAT with and without a complete blood count (CBC)) prior to doctor evaluation. The incremental cost effectiveness ratio (ICER) was used to perform the cost effectiveness analysis.
Results: There were 248 patients enrolled in the study. The use of the two upfront, POC test pathways significantly exceeded the primary outcome measure of a 20% reduction in treatment time. In the i-STAT + CBC group, the 31 min. time-saving translated into cost-saving of US$14.96 per patient (IECR 0.27) whereas the 21 min. time-saving in the i-STAT only group only had an additional net cost of US$3.11 per patient (IECR 0.90).
Conclusion: Upfront, POC blood tests can be utilised in the resource-constrained EC to manage patients more efficiently by saving time. This time-saving can, in fact, be more cost effective than traditional EC workflow making it an economically viable option for implementation in LMIC.

African Relevance

· Access to laboratory services in LMIC is commonly inadequate
· Point-of-Care (POC) blood tests may be a possible solution
· Upfront, POC tests are time-saving and can be cost-effective

Introduction

Time is a valuable commodity in the Emergency Centre (EC). From the institution of time-critical interventions to targets applied to the time a doctor can spend with patients – The staff in the EC are constantly competing against the clock.

Almost half of all patients presenting to the EC require laboratory tests [1,2]. Unfortunately, access to laboratory services in low- and middle-income countries (LMIC) is commonly insufficient [3]. Point-of-Care (POC) testing (near-patient or bedside diagnostic testing that

occurs outside the laboratory) is a potential solution to this problem but it has shown both positive and negative results with regards to time- and cost-saving when instituted in ECs worldwide [4–10]. There are various POC blood test options available which have been shown to have equivalent accuracy to formal laboratory testing [10,11]. The convenience and time-saving associated with these bedside tests usually comes at a cost, however, as POC tests are commonly more expensive than traditional laboratory tests [8,9,12].

Traditionally, in the EC, blood tests are performed after a doctor has assessed the patient. The use of protocolised testing prior to doctor review has been evaluated previously in the form of standing orders. These standing orders, however, have not utilised POC devices or have only been instituted when the EC is full. There has also been inconsistent uptake by staff with resultant inappropriate testing [13,14]. Significant time-saving has recently been shown with upfront, POC testing performed prior to the patient being assessed by the doctor in

the EC [15].

The aim of this study was to evaluate the cost-effectiveness of up-front POC blood tests performed prior to doctor assessment compared to the standard EC workflow.

Methods

A secondary analysis was performed on data from an investigator-initiated, prospective, randomised, controlled trial that evaluated the cost-effectiveness of upfront, POC tests in the EC. It took place in a tertiary, academic hospital EC in Johannesburg, South Africa. The EC has an annual census of approximately 65 000 patients, the majority of whom (70%) have non-traumatic pathologies.

Although the original randomised, controlled trial evaluated multiple POC tests, this secondary analysis will focus on the cost implications when only POC blood testing is utilised. In LMIC ECs, blood tests would be the easiest POC test to implement and the one with the least capital outlay (versus purchasing ECG machines or a LODOX® (LOw DOse X-ray) machine).

The Research Ethics Committee of the Faculty of Health Sciences of the University of Johannesburg (REC-01-185-2016); the Human Research Ethics Committee of the University of the Witwatersrand (M171086) and the South African National Health Research Ethics Council (DOH-27-0117-5628) all granted permission to conduct the study. Registration as a clinical trial was through with the South African National Health Research Database (GP_2017RP57_655) and with clinicaltrials.gov (NCT03102216). All patients provided written informed consent.

A convenience sample of adult, non-pregnant patients, older than 18 years of age, who presented to EC during weekdays qualified for inclusion. Patients requiring immediate resuscitation were not included.

Patients with "abdominal complaints", "chest complaints", "generalised body pain/weakness" and "psychiatric complaints" were approached for participation. "Abdominal complaints" included abdominal pain and/or nausea and vomiting. "Chest complaints" included dyspnoea, chest pain, syncope and/or cough. "Psychiatric complaints" included patients with hallucinations, aggression, psychosis or who had taken an overdose.

Each patient was randomised into a workflow pathway as detailed in Fig. 1. Prior to the commencement of the study, block randomisation of the three workflow pathways (viz. Control, i-STAT and i-STAT + CBC) took place using an online randomisation tool (www.randomizer.org). Three cardboard boxes (one for each symptom group) each had blocks of data collection sheets placed upside-down in them in the order generated by the randomiser. After consent and enrolment, the research doctor/research assistant took the next available data collection sheet from the appropriate symptom box.

In the control group, a doctor would see the patient after the triage process. The doctor then ordered diagnostic tests that they considered to be clinically indicated. The requested blood tests were performed in the hospital laboratory that was on-site. This was done according to standard procedures. If the doctor required a blood gas analysis to be performed on the patient, s/he would perform the procedure and process the specimen on one of two blood gas analysers that were present in the EC (Cobas B 221 POC system, Roche Diagnostics or ABL800 Flex, Radiometer). The doctor would then need to wait to review the patient a second time once the test results were available after which a patient disposition decision was made.

In the two enhanced workflow groups, the patient had the POC blood tests immediately after triage and was then seen by a doctor. If the doctor deemed extra investigations necessary in addition to the POC tests, then those tests were performed as per the standard procedures. The POC enhanced workflow patients would then also be reviewed a second time (like the control group) once the results of the additional tests were ready.

The time taken for patient throughput in the EC consists of both administrative and treatment times [16]. The administrative time is the time from patient arrival to the time of doctor evaluation. In our hospital, it is the time where the patient is registered in the hospital computer system and a file is opened. This process is a prerequisite for all patients. The time taken for patient registration can, however, vary from day-to-day and hour-to-hour. In order to avoid the potential confounding effect this would have on an intervention, only the treatment time was used as the comparator. Treatment time is the time taken from doctor evaluation until the time the decision for the patient's disposition has been made. Decision disposition time was chosen rather than the time the patient physically departed the EC due to extrinsic factors such as exit block confounding the impact. The original study focused on the time-saving aspect of the POC interventions [15].

The POC tests that were evaluated are shown in Table 1.

The POC blood tests were performed in the EC within a private cubicle. Standard EC procedure was followed for all other diagnostic testing. The time data obtained from the original study was utilised [15]. The costs of the diagnostic tests incurred in the control group were compared to the i-STAT and i-STAT + CBC groups.

The on-site hospital laboratory provided the prices for the control pathway investigations. The i-STAT and CBC costs were obtained from their actual EC usage prices. All test costs were considered to be inclusive of capital and maintenance costs of equipment.

Staffing cost calculations were performed as suggested by Schilling [8]. They were calculated using doctor and nursing costs only with staffing considered to be distributed evenly during the year: Staffing cost per minute (US$/minute) = Total EC staffing cost/Total minutes per annum

The mean time between two patient arrivals was calculated under the assumption of a statistically constant flow to the EC based on 65 000 annual visits (8.09 minutes between new patient arrivals). The average length of stay was calculated using the time for the control population. The average number of patients in the ED requiring attention was the average length of stay divided by the mean time between two new patient arrivals. The staffing cost per patient minute was then based on this time.

The cost-effectiveness of upfront, POC tests was the main outcome measure of this study. The incremental cost effectiveness ratio (ICER) expressed as: ICER = (C1 − C2)/(E1 − E2), was used to perform the cost effectiveness analysis. In this formula, C1 and E1 are the cost and effect (treatment time) of the intervention group and C2 and E2 are the cost and effect of the control group [9].

The statistical analysis of the time component of the study can be found in detail in the supplementary appendix. Data analysis was carried out using SAS (version 9.4 for Windows). The 5% significance level was used throughout.

Results

Enrolment of 248 patients took place between 13 February and 29 June 2017. An interim analysis during data collection in the primary study showed that the outcomes for the "psychiatric complaints" group were very different from the other three symptom groups. Based on their triage scores, the psychiatric patients were seen almost immediately in most cases and commonly only needed a blood gas analysis to be performed. It was therefore a group that was already "functioning at optimum" from an EC throughput perspective and the extra testing was not required. Their inclusion would have skewed the data unnecessarily. Fig. 1 summarises the three symptom groups' patient distribution. A comparison of patient characteristics is in Table 2.

Fig. 2 shows the mean treatment times across the three workflow permutations when all the symptom groups are combined. The treatment time was significantly shorter compared to the control workflow if the patient received an i-STAT + CBC (p = 0.0001).

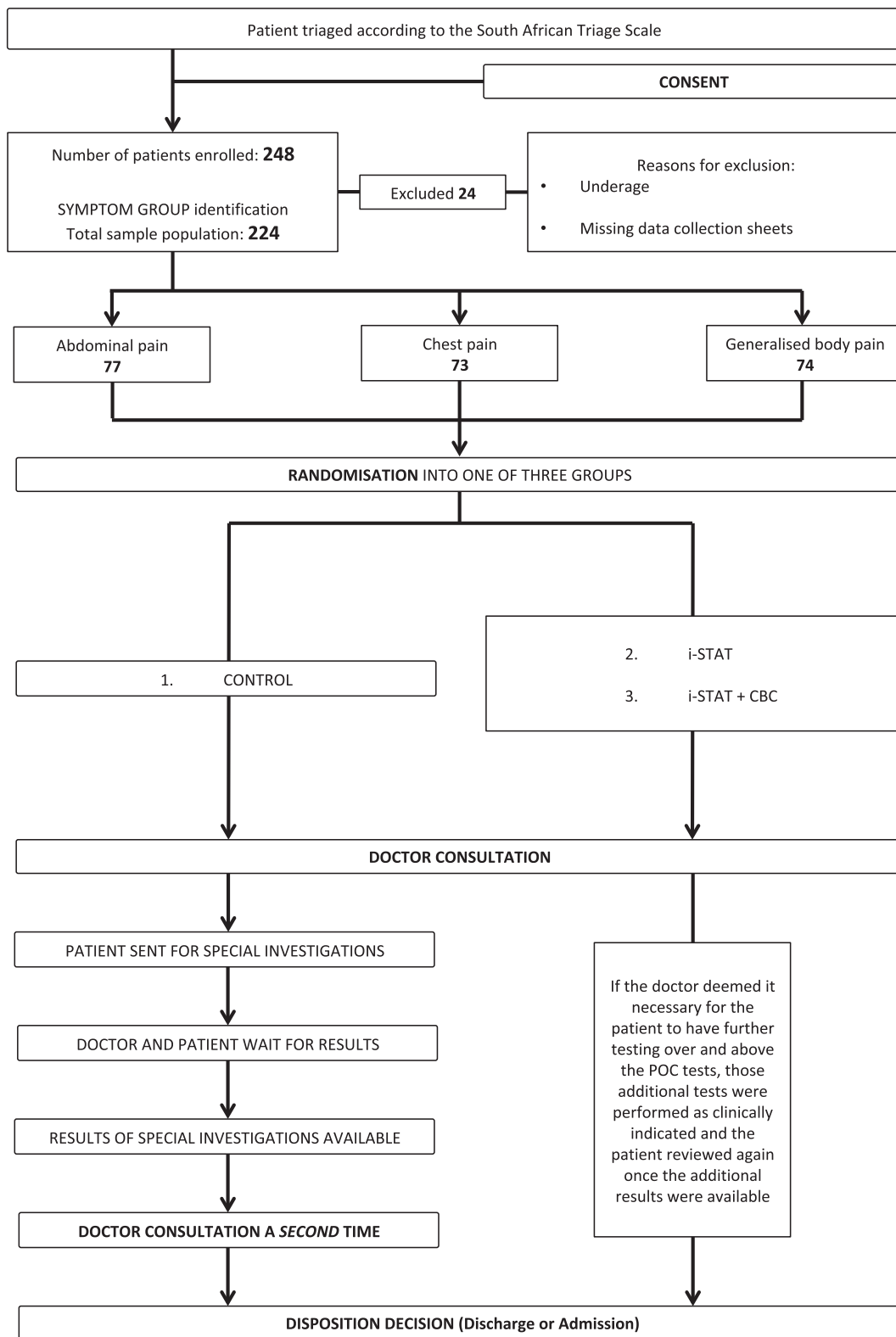The primary outcome in the time study (a 20% reduction in

Fig. 1. Flow chart showing randomisation and data collection procedure.

treatment time indicated by the horizontal red line) was significantly exceeded in both POC intervention groups.

It took between 9 and 12 min. to obtain the results of the POC tests. This included the time taken for phlebotomy as well as specimen processing and results printing. The tests could generally be performed

The individual investigation costs are tabulated in Table 1. If all the

tests were performed in any patient, the POC equivalent tests would cost US$7.48 more per patient.

The average treatment time for the control patients was 58 mins. Based on this value, there would have been 7.2 patients in the EC at any given time (this excludes patients waiting for disposition).

One minute of EC staffing cost US$5.37, which is equivalent to US

Table 1

POC blood tests employed and the costs of the control pathway blood tests and their POC equivalents.

Abbott Point-of-Care i-STAT® System			
The i-STAT System (i-STAT, Abbott Point of Care, Princeton, NJ, USA) consists of single-use i-STAT test cartridges placed into a handheld POC blood analyser. The CHEM8+ (sodium, potassium, chloride, total carbon dioxide, ionised calcium, glucose, urea, creatinine, haematocrit, haemoglobin and anion gap) and CG4+ (Lactate; pH; partial pressure carbon dioxide (PCO_2); partial pressure of oxygen (PO_2); total carbon dioxide; bicarbonate; base excess and oxygen saturation) i-STAT cartridges were utilised. Venous blood specimens were phlebotomised			
Abbott CEL-DYN Emerald 22 benchtop haematology system			
A POC Complete/Full Blood Count (which included a differential white blood cell count) was provided by the CEL-DYN Emerald 22 benchtop haematology system			
Lab blood tests	Cost	Point-of-Care equivalent	Cost
Complete Blood Count	4.57	CBC (CEL-DYN Emerald 22)	2.33
Electrolytes, Urea, Creatinine	13.62	Chem8 (i-STAT)	16.15
Blood Gas Analysis	4.27	CG4+ (i-STAT)	11.46
TOTAL	$ 22.46	TOTAL	$ 29.94

$, Costs shown in US dollars; CBC, Complete Blood Count; i-STAT, i-STAT POC test

Table 2

Patient characteristics.

Sample variables	CONTROL	i-STAT	i-STAT CBC	p-value for between group test
Age median (IQR)	50.6 (39.4; 66.9)	48.1 (34.8; 61.2)	49.5 (36.1; 68.4)	0.74
Sex: Males (%)	30 (40.0)	30 (40.0)	29 (39.2)	0.96
Triage category N (%)				
Orange*	22 (29.3)	18 (24.0)	11 (14.9)	0.43
Yellow*	52 (69.3)	54 (72.0)	60 (81.1)	0.43
Green*	1 (1.3)	3 (4.0)	3 (4.1)	0.43
Admitted§ N (%)	32 (42.7)	32 (42.7)	40 (54.1)	0.46
Discharged§ N (%)	38 (50.7)	41 (54.7)	33 (44.6)	

§, 8.2% of all patients were neither admitted nor discharged but rather referred to another speciality to be seen in the EC; *, Target times for the patients in each triage acuity category according to the South African Triage Scale: Orange – to be seen within 10 minutes of EC arrival, Yellow – to be seen within 1 hour of EC arrival, Green – to be seen within 4 h of EC arrival

$0.75 per patient per minute. The control and intervention time-saving and costs are presented in Table 3.

The cost effectiveness analysis is graphically presented in a Cost Effectiveness Plane in Fig. 3.

Discussion

Saving time is a common goal in emergency medicine and LMIC resource-constrained ECs are no different. Sometimes we can be surprised when things that we think will come at a higher cost actually end up being cost-effective. While upfront POC testing has been shown to improve treatment times, it was essential to assess whether it could be an economically viable model for use in limited-resource settings [15].

No significant differences existed between the patients in the control or POC intervention groups. This was irrespective of age, sex, triage category and disposition decision.

Both the i-STAT only and i-STAT + CBC groups demonstrated clinically significant time-saving across the three symptom groups [15]. The use of i-STAT alone, however, did not reach statistically significant time-saving compared to the control group. This may be accounted for by the heterogeneity of and within the symptom groups included in this study e.g. "chest symptoms" versus "abdominal symptoms" versus "generalised body pain and weakness" and "chest symptoms" ranging from cough to syncope. The time-saving from the institution of POC tests for isolated "chest pain" and isolated "abdominal pain" has previously been demonstrated [17,18].

The utilisation of blood tests in order to make a disposition decision is commonplace in the EC [1,2]. It is, however, also a "rate-limiting step for many patients" [10,19]. In Yoon's study, blood testing added 126 minutes to the patient's length of stay [1]. EC patient length of stay was increased by 35.4–40.1 mins if they received any blood test in Gardner's evaluation of factors influencing patient EC length of stay [20]. In our study, all patients in the intervention POC groups had a decrease in their treatment time.

The ability to perform the intervention POC tests concurrently and the quick result turnaround time meant that the time taken to perform them did not cause any significant delays for the patient to be assessed by the doctor. Waiting for results was concurrent with the wait to be seen.

Waiting for the results of special investigations including blood tests comprises two-thirds of a patient's entire EC length of stay [1]. By performing the POC tests during the time that would normally be spent waiting to see the doctor, a considerable amount of time could be saved in the patient's overall time in the EC.

Frequently quoted barriers to the adoption of POC testing in the EC
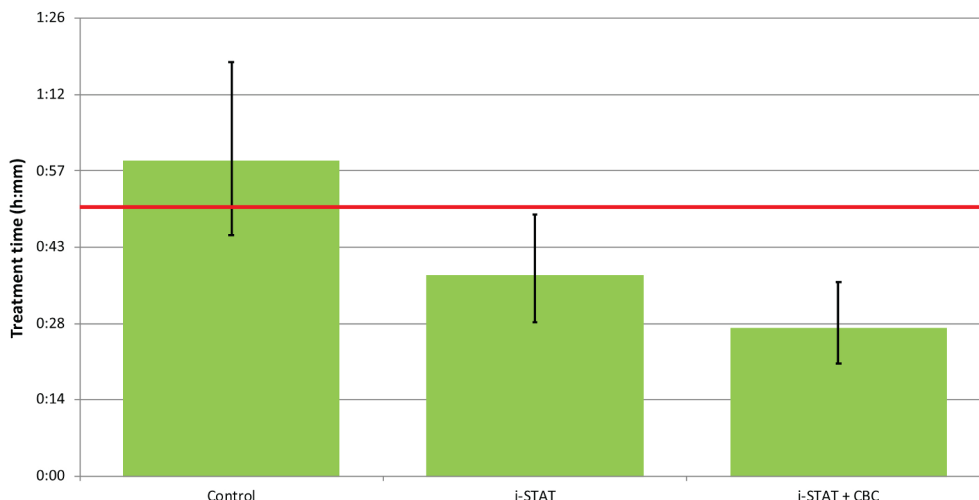
Fig. 2. Mean treatment times for the control and POC workflow permutations (combined symptom groups).

Table 3
Costs and time-saving analysis.

Variable	Total Cost (US$ pp)	Difference between costs of POC tests and control (US$ pp)	Time Saved – Difference between control group time and POC group time (min)	Staffing costs saved (US$ pp)	IECR - Incremental Cost Effectiveness Ratio (US$ / min)	Net additional cost per patient in POC group (US$ pp)
Control	10.53	–	–	–	–	–
i-STAT	29.37	18.84	21	15.72	0.90	3.11
i-STAT + CBC	18.79	8.26	31	23.21	0.27	−14.96

CBC, Complete Blood Count; i-STAT, i-STAT POC tests; pp, per patient.

include quality assurance, reliability of results and higher per test costs for POC compared to centralised laboratory testing [10,12]. There are various POC blood test options available which have been shown to have equivalent accuracy to formal laboratory testing [10,11]. Each POC device has their own quality control procedure that should be performed as per manufacturer's guidelines. Ease of availability leading to over-testing is a further barrier commonly cited with regards to POC testing. It has, however, been shown not to be factor when formally evaluated [15,18].

Previous studies have reported variations in the actual costs of implementing POC testing. Some have reported increased costs and others showed an overall reduction in costs [8,9].

A face value comparison of the direct costs of implementation of POC tests in our EC compared to standard laboratory referral meant an additional cost of US$7.48 per patient. This, however, needed to be offset against the time-saving offered from the upfront, POC tests, hence the cost effectiveness analysis.

When the effects of the costs for staffing as well as the time-saving were considered, the result was a net additional cost of only US$3.11 if the patient received an i-STAT and a saving of US$14.96 if the patient received an i-STAT as well as a CBC. The relatively lower cost of the POC CBC compared to the laboratory CBC together with the additional 10 minute time-saving contributed to this overall cost saving.

Schilling's study on the economic impact of POC testing in a Swedish EC showed a significantly higher cost saving compared to our study. This was mainly due to the lower cost of POC tests in their setting as well as their higher cost of staffing (US$24.08/min versus our US$5.37/min) [8].

The RATPAC Trial for chest pain in suspected myocardial infarction in the EC showed that POC was associated with higher EC costs but lower inpatient costs for that group of patients [21]. Our study looked at the economic impact of POC in the EC only – Further cost saving from lowering inpatient admission rates and therefore costs may be further benefit that will need to be studied.

The impact of non-fiscal "cost savings" should perhaps be evaluated in future POC cost-effectiveness analyses. The decrease in patient complaints due to excess waiting times, the increase in staff satisfaction, and the potential for fewer patients leaving the EC without being seen are positive effects which need to be quantified.

Four barriers have been identified in implementing good quality pathology and laboratory medicine in LMIC: insufficient human resources, shortage of education and training, inadequate infrastructure, and insufficient quality, standards, and accreditation [3]. From the emergency medicine perspective, POC tests are simple, quick and relatively affordable (compared to the costs of opening and running a laboratory) option that can be used in the LMIC resource-constrained environment in order to safely and timeously make our disposition decisions. The unit cost per test of POC is larger than that of the laboratory due to the loss of the economy of scale offered by automation [9]. Nonetheless, the rapidity of result availability and time-saving of POC has the potential advantage of overcoming the four barriers faced by LMIC.

This was a single centre study. Patient outcome effects such as morbidity and mortality were not assessed and could be a focus for future POC studies. Even though the EC doctors were not blinded to control versus intervention patients, a Hawthorne-type effect was not evident. Time recording could have been a hypothetical source of error as the doctors themselves documented these. The use of synchronised clocks throughout the EC would have helped to ameliorate this but does not negate the human factor. Staffing costs were calculated using doctor and nursing costs only due to the funding of allied hospital staff being managed separately. There was no analysis performed for over-testing, however, previous studies have shown that this is not likely. As patient enrolment only took place during weekdays and not on weekends or at night, the possibility of selection bias exists. Patient inflow at night is usually less than during the day which would make it a confounder for
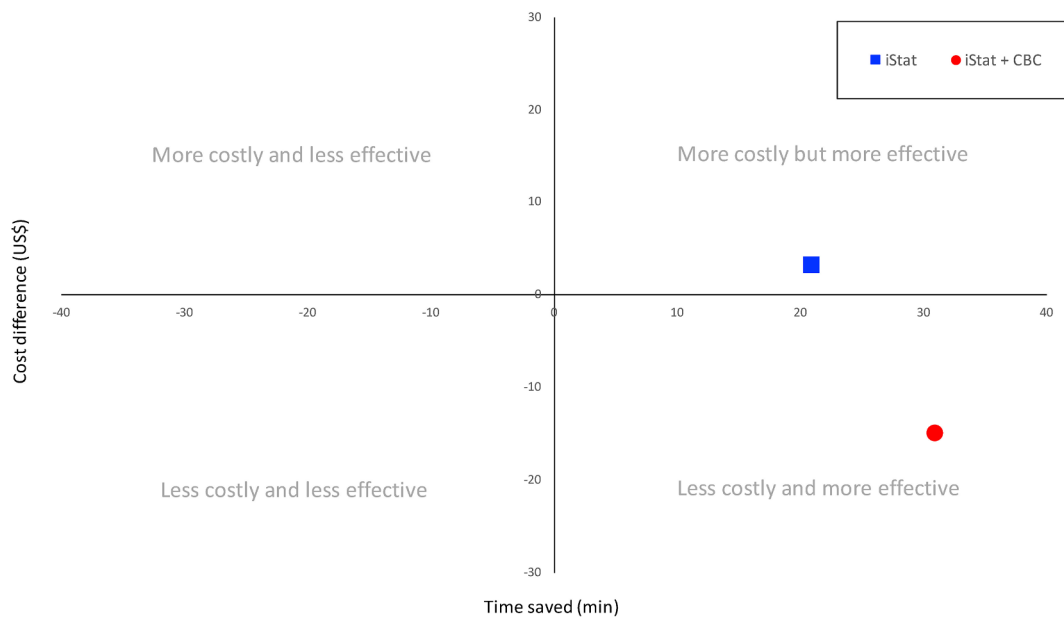
Fig. 3. Cost effectiveness plane.

comparison purposes. Weekend EC attendance also varies substantially depending on the time of month. At times, the EC is even busier than on weekdays, which may have shown the POC interventions to be even more beneficial. Inclusion of weekends would therefore have potentially confounded the results.

Conclusion

The institution of upfront, POC tests in the EC for patients presenting with chest, abdominal or generalised body pain complaints can save time. The utility of these tests mean we can manage patients more efficiently as well as being cost-effective even in a LMIC resource-constrained environment.

Dissemination of results

Dissemination will occur in the form of publications and academic presentation.

Author contribution

Authors contributed as follow to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: LG, MW and CL each contributed 33%. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

Conflicts of interest

Profs Lara Goldstein, Mike Wells and Craig Lambert are editors of the African Journal of Emergency Medicine. Profs Goldstein, Wells and Lambert were not involved in the editorial workflow for this manuscript. The African Journal of Emergency Medicine applies a double blinded process for all manuscript peer reviews. The authors declared no further conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.afjem.2019.01.011.

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